# The Foundry Trade Journal

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## Contents.


| | PAGE |
|---|---|
| Notes and Comments | 207 |
| Heroult Electric Furnace at Braintree | 208 |
| An Inquest on a Waster | 209 |
| Steel Castings and the Effect of Heat Treatment | 212 |
| Casting Steel and Alloys in a Vacuum | 217 |
| The Microscopic Structure of Brass and Bronze | 221 |
| Making Ingot Moulds in Dry Sand | 223 |
| Manufacture of Balls for Bearings | 227 |
| Electric Furnaces | 226 |
| Some Castings Troublesome to Run up Sound | 231 |
| Indian Iron and Steel | 232 |
| British Foundrymen's Association (Annual Dinner of the Sheffield Branch) | 234 |
| Manufacture of Steel in the Girod Electric Furnace | 235 |
| The Hering "Pinch Effect" Furnace | 238 |
| Foundry Plant and Equipment | 240 |
| The Oerlikon Centrifugal Disentegrator for Moulding Sand | 241 |
| Correspondence | 242 |
| Queries | 242 |
| Inventions | 243 |
| Trade Talk | 243 |
| Personal | 246 |
| New Companies | 248 |
| Deaths | 248 |
| Prices of Metal | 250 |


## Forthcoming Events.

APRIL 12.

*British Foundrymen's Association* (London Branch).—"The Application of the Microscope in the Foundry," by G. Hailstone.

APRIL 13.

*British Foundrymen's Association* (Scottish Branch).—Annual general meeting.

APRIL 16.

*British Foundrymen's Association* (Sheffield Branch).—"The Stock Converter Process," by Mr. Stock.

APRIL 20.

*British Foundrymen's Association* (Halifax Branch).—"Segregation and Crystallisation of Cast-iron," by E. L. Rhead.

APRIL 27.

*British Foundrymen's Association* (Birmingham Branch).—"Melting Iron in the Cupola, and Cupola Practice," by H. Pemberton.

*British Foundrymen's Association* (Newcastle Branch).—"Modern Foundry Practice," by J. Smith.

## NOTES AND COMMENTS.

### A Suggested Economy in Open-Hearth Furnace Working.

A question of grave importance in industrial operations is the possible conservation and utilisation of one-time waste products, and each year sees some further advance, either in the more complete utilisation of materials, or the application to definite uses of what was formerly allowed to escape as waste. In the field of power-plant operations particular advance has been made of late years, both in the economising of fuel and in the increased efficiency of the mechanism. But less effective attention has been paid to the enormous amount of energy which is continually going to waste in the course of furnace operations. It is true that in smelting works the waste heat is utilised for steam raising, though even then the gases pass away into the chimney stack at temperatures which imply a large waste of heat. Open-hearth furnace operations on the regenerative principle, too, may be claimed to utilise a considerable amount of otherwise waste heat, but still the gases leave the open-hearth furnace at a temperature of 600 to 700 deg. C. The important possibility of using this waste heat is discussed in an article by F. Mayer, published in our German contemporary, "Stahl und Eisen." That writer states that the heat balance of the open-hearth furnace plant is approximately as follows, expressed in percentages of the total heat generated by the coal consumed:—

| | Per cent. |
|---|---|
| Total net useful effect | 27 |
| Losses by radiation from furnace & producers | 29 |
| Loss of heat in the waste gases | 31 |
| Combustible matter in producer cinders | 3 |
| Loss by radiation from producer | 10 |
| | 100 |

It is evident, therefore, that the useful effect of the whole plant could be considerably increased by an improvement in the utilisation of the very high losses sustained in the waste gases; but at present, no means are available for recovering the waste heat from the gases for utilisation in the furnace plant itself. The idea of increasing the size of the gas producers so as to obtain a higher degree of preliminary heating of the gas and air, and thus utilise the heat of the waste gases more effectually, Mr. Mayer dismisses as impracticable, because the pre-heating already raises the gas and air temperatures to that of the waste gases, and therefore cannot be improved upon. Consequently, the only course open for the time being is to utilise for extraneous purposes any waste heat that is capable of being recovered, steam raising being the most important to be considered. In utilising the waste heat of the gases so as to lower their temperature from 600—700 to 300 deg. C., about 1¾ tons of steam, at a pressure of 146 lbs., could be raised per hour from a 34 to 35-ton open-hearth furnace, consuming 27 cwts. of coal, with a heating value of 28,500 B.Th.U. Assum-

ing 1 lb. of coal to produce 8 lbs. of steam, and that the steam would be utilised day and night for 300 days in the year, this would correspond, in the case of the above furnace, to a saving of 4½ cwts. of coal per hour, or, with coal at 16s. per ton, to an annual saving of £1,330. This saving of coal, amounting to 16.7 per cent. of the total consumption, would amend the heat balance as follows:—

| | Per cent. |
|---|---|
| Total useful effect ... ... ... | 27+16.7=43.7 |
| Losses by radiation from furnace & producers | 29.0 |
| Loss in waste gases ... ... .. | 31.0—16.7=14.3 |
| Combustible matter in producer cinders ... | 3.0 |
| Loss by radiation from producer ... ... | 10.0 |
| | 100.0 |

The total efficiency of the open-hearth steel plant is thus improved to the extent of 16.7 per cent. by the provision of a waste-heat boiler. An important point to remember is that the furnace draft should not be interfered with in the slightest degree by the interposition of such a boiler, the production of steel being the main factor in the working of the furnace. Consequently, the chimney stack must be able to produce the same draft in the furnace as before, in spite of the frictional resistance opposed by the boiler surfaces to the passage of the gases. The fulfilment of this condition would necessitate an increase in the height of the stack. In many cases this increase would be too great to be obtained with the existing stack, and either a new stack would have to be built, or artificial draft created. In either case, the initial outlay would be recouped in 1½ to 2 years. With artificial draft, the provision of an economiser behind the waste-heat boiler would enable the temperature of the waste gases to be reduced to 150—200 deg. C., thus increasing the output of steam by about 20 per cent. The question is well worth the attention of steel-works engineers.

### The Question of Special Elements in Cast Iron.

In reference to the advisability of using such special elements as vanadium in cast irons, a correspondent expresses the doubts on the subject which probably are experienced by many founders. Very often is the "medicine chest" (to use a term applied to the scavengers, deoxidisers, and other additions which have at different times been recommended for cast iron) referred to contemptuously by foundrymen; for such additions are frequently regarded as bad substitutes for good workmanship in the mixing and melting of the metals. It is wrong, however, to condemn, without exhaustive trial, the addition of unusual elements to cast iron. Cast iron itself is a highly complex alloy of six or more elements, some of which exist in only minute proportions, though with immense influence on the condition of the whole alloy; and the experience of steel makers in the effect of special elements should go far to discount the suggestion that the usual contents of commercial irons comprise all the elements which can be usefully contained. At the same time, British founders will be loth to accept evidence of the advantages of vanadium based on American practice; and there does not appear to be sufficient data as to that element's use with British irons to justify definite conclusions. Briefly, the claims for vanadium, as applied to iron, are as follows:—(1) That it acts as a unique scavenger. It has a high affinity for oxygen, and at the heat of molten metal it decomposes and diffuses any sub-oxide which may be in the metal, the vanadium oxide, a dead fusible body, rising at once to the surface and being carried off in the slag. Also, that it has a great affinity for nitrogen. (2) That it causes all the constituents of the carbides to be more closely packed. (3) That it has an important strengthening effect by means of its actual presence as a constituent of the complex carbides, giving a metal distinctly stronger, much tougher, and more resistant. There are many who deny that oxides exist in the iron for the vanadium to remove, and that in any case silicon, with its great affinity for oxygen, would deal effectively with any of that gas which entered. Mr. Kent Smith, however, having found part of the vanadium in the slag, concludes that it got there as the result of removing oxygen. We must admit the evidence is not conclusive; nor does the fact that the poorer the iron the greater is the amount of vanadium so used up in scavenging afford material aid to a solution of the problem, unless the iron experimented with is fully analysed before and after treatment. Nitrogen may offer a solution, but that element is practically an unknown quantity (though not necessarily absent) in cast irons, for only in very special researches is it determined. As regards the effect of vanadium on the carbides, Mr. Kent Smith claims that his views are supported by Mr. W. H. Hatfield's experiments; but until these points are definitely established we are thrown back on the results of practical tests in forming an opinion as to the merits of the claims.

What, then, of the practical tests mentioned by Mr. Kent Smith? Amongst others he quoted a cylinder iron which normally had a tensile strength of 10.7 tons, which figure was raised to 14.25 tons by the addition of 0.2 per cent. of vanadium. Another cylinder iron had its tensile strength increased from 11.6 tons to 16.5 tons, and another, made in the air furnace, from 13.4 tons to 14.7 tons, the percentage of vanadium in both cases being 0.15. As regards transverse tests, one instance mentioned was that of an iron which failed under standard conditions at 1,300 pounds, but which, when vanadised with 0.125 per cent., sustained a transverse test up to 2,200 pounds. In another case, with a similar style of iron, the increase was from 1,400 pounds to 1,900 pounds with 0.15 per cent. of vanadium; while with a fair specimen of cylinder iron, the transverse test was raised from 2,500 pounds to 3,400 pounds. Another iron of better quality made in an air furnace had an initial strength of 3,700 pounds, which was raised to 4,200 pounds. As regards compressive strength, too, it was claimed that vanadium had raised the standard from 60 tons per square inch to 67 tons with one iron, and with another rather harder iron from 65.2 tons to 71.5 tons by the addition of 0.15 per cent. of vanadium. With a chilled iron the increase was from 96 tons to 112 tons.

If these results be accepted, no matter what disputes are waged round the chemical influences of vanadium, there is at least an influence on the mechanical properties which requires investigating. Whether the figures quoted would stand as representative in the case of British irons is, of course, open to question; but they must either be denied altogether, or some beneficial effect must be admitted, even though the hypothesis of Mr. Kent Smith's arguments be quite erroneous.

If, then, we accept the evidence that vanadium has some beneficial influence on some cast irons, it remains for practical experiment to ascertain to what extent that influence can be exercised in connection with such irons as are in general use for different classes of work. Only by comparative tests with the same metal vanadised and unvanadised, and applied to the same casting, can a satisfactory decision be arrived at; there are too many factors

influencing the mechanical properties of cast metals for general figures resulting from other than strictly comparable tests to be of much value. It further remains for the laboratory to ascertain the exact nature of the effects of vanadium, should it be proved conclusively to be beneficial to all irons; then the foundryman will be able to work intelligently in the light of scientific instruction and not by haphazard methods. There is also the important consideration of cost affecting the acceptance of vanadium as a popular addition to cast iron. The price of vanadium, it is stated, fluctuates, but its use costs about an average of 3s. per cwt. on a casting. The question directly arises as to whether this addition of £3 a ton onto the cost of the metal is justified by the improvement obtained, and whether a better iron unvanadised would not come cheaper. This can only be determined by experience. The highest results quoted by Mr. Kent Smith are not encouraging to British foundrymen accustomed to the handling of first-class irons. What the effect of vanadium on those irons would be remains to be seen.

### Steel for Permanent Magnets.

Not many British steel makers attempt the production of steel for permanent magnets, though the developments in internal-combustion engineering during the last few years have opened quite a considerable field in this direction. In the very early days of dynamo-electric machinery permanent magnets were used exclusively, but when the principle of self-excitation was discovered, permanent magnets fell into disuse, and magnet steel for dynamos had then to be made as soft as possible, and with a minimum of residual magnetism. Permanent magnet machines, however, did not altogether go out of existence, because as magneto generators they were required for telephones and in medical work. Only a few were made, however, until internal-combustion engines, especially those using heavy oil and petrol, came on to the market. At first the gases in the cylinders of such engines were fired by accumulator cells, but it was soon recognised that the magneto was best fitted for the job, and it is now employed almost universally. Petrol engines for motor cars, motor cycles, motor boats, and for aviation are all fitted with magnetos, and to-day many thousands of the machines are being made in France, Germany, the United States, and in this country. Although quite small machines, they are made in such numbers that the demand for permanent-magnet steel has become quite an important one. The bulk of the steel used, known as Remy steel, is made by a single German firm. Other steel-makers, including one well-known firm in Sheffield, have attempted its production, but Remy steel still appears to hold the field.

Under a grant from the Carnegie Institution at Washington, Messrs. C. F. Burgess and J. Aston have made magnetic tests on about 100 samples of steel containing chromium, manganese, molybdenum, nickel and tungsten, as binary alloys or in various combinations with other metals. The results of the investigations were embodied in a Paper recently read before the American Electro-Chemical Society. Amongst the specimens many showed low permeabilities and high coercive forces, suggesting their utility for permanent magnets. The most desirable feature of a permanet magnet is that it shall have as high a residual magnetism as possible, or, better still, that it shall have a high retentivity after some disturbing factor has tended to destroy the residual magnetism. It must also have a high coercive force to resist the tendency towards this loss of the magnetic flux. The tests of six of the best bars from a permanent-magnet point of view were as follows:—

| Bar. | Composition. | Residual Magnetism. | Coercive force |
|---|---|---|---|
| 136M | 5Cr 3Mn 4Mo 1Sb | 11,350 | 55.8 As forged |
| 136V | 10Ni 5Mo | 10,150 | 36.7 ,, |
| 150C | 2Cr 10Mo 0.5C 0.3V | 10,500 | 78.0 Quenched |
| 155Y | 10Ni 5W | 10,300 | 35.2 ,, |
| 156A | 1Mn 2Mo | 10,500 | 39.6 ,, |
| 155P | 1Mn 10Mo 0.5C. | 10,750 | 58.4 ,, |

A feature of bars 136V and 155Y is the high nickel content. Generally speaking, increase of nickel causes a decrease of retentivity and increase of coercive force, until at about 26 per cent. nickel the material is non-magnetic. Beyond this percentage the magnetic properties are restored, the alloys being of rather higher permeability and low coercive force. It is interesting to note that the addition of chromium alone to carbonless iron does not result in a material suitable for permanent magnets; but the further addition of 0.75 to 1 per cent. of silicon or 0.3 to 0.5 per cent. of carbon to 5 or 6 per cent. of chromium is highly beneficial, and gives a very suitable alloy. The effects of quenching were varied. In 13 instances there was a considerable increase of coercive force, in 30 cases but little change, and in six instances a marked decrease. In four cases bars which were originally poor became of fair quality after quenching; and in numerous instances the quality of fair materials was greatly improved; in no case, however, did quenching result in a bar of fair quality becoming poor material for permanent magnets. The residual magnetism after shock showed a decrease of about 50 per cent.

Investigations of the best steel for permanent magnets are worth conducting, because the prices which are now being paid for Remy steel are ridiculously high. The production of magnetos from the various factories where they are made is increasing very rapidly, and there is no indication of any decrease in the demand for permanent-magnet steel.

## American Foundrymen's Association

### Forthcoming Annual Convention.

The annual Convention of the American Foundrymen's Association, and its allied Associations, will be held in Buffalo, September 24, 25 and 26, 1912. The headquarters will be in Hotel Statler, at which place the sessions will also be held. An elaborate exhibition has been promised by the Foundry and Machine Exhibition Company.

Owing to the unprecedented severity of the winter just passing, it was impossible to complete the Exhibition buildings provided by the City of Buffalo in time for the regular May gathering. The buildings in question were remodelled at the cost of over £30,000. It was therefore decided to postpone the convention until September.

The Association have received an invitation from the Executive Committee of the Eighth International Congress of Applied Chemistry, to take part in the proceedings of that body. The opening meeting will be held in Washington, September 4, 1912, and subsequent sessions in New York City.

THE capital of Corbyns Hall Iron and Steel Works, Limited, has been reduced to £5,793, divided into 600 preference shares of £1 each, 3,400 preference shares of 10s. each, and 3,493 ordinary shares of £1 each, instead of the former capital of £10,000, divided into 4,000 preference shares of £1 each and 6,000 ordinary shares of £1 each.

# Heroult Electric Furnace at Braintree.

A Héroult electric furnace has now been in operation for about a year at the works of Messrs. Lake & Elliot, at Braintree, Essex. This furnace, which is of two tons' capacity, is being employed to make steel for castings, especially for the automobile trade. Before the introduction of the electric furnace the steel for the castings was made entirely in crucibles.

The plant is of special interest, not only because this is at present the only works in England where an electric furnace is being employed solely for foundry work, but also because it is in a district where cheap power is unobtainable, so that Messrs. Lake & Elliot have been compelled to generate their own power. The generating plant consists of a gas producer, and a Westinghouse gas engine, to which a single-phase alternator is directly coupled. The gas producer is of the modern type, bottom and top

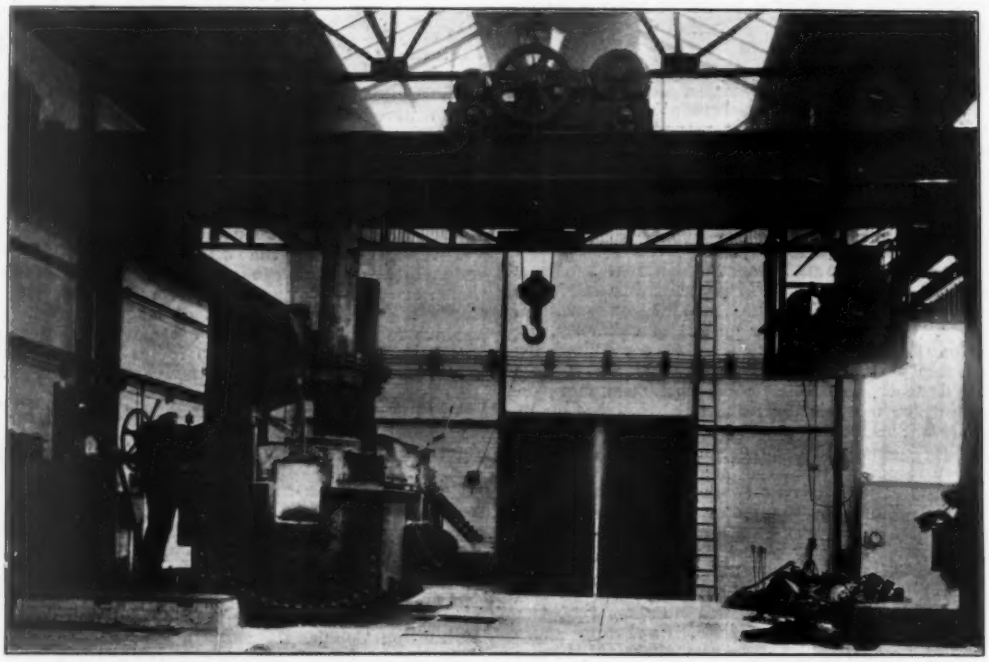

Fig. 1.—General View of Heroult Electric Furnace at Braintree.

fired. The gas engine is of the vertical tandem type, with eight cylinders and four cranks, and is capable of giving 450 b.h.p. continuously, and 500 b.h.p. for periods of half an hour. The alternator is capable of giving 450 b.h.p. continuously, and 500 b.h.p. for volts. The current is single-phase alternating, and the periodicity 25 cycles per second.

The furnace is of the Héroult single-phase type, using two round electrodes, 14 in. in diameter. The stub ends are fastened on to new electrodes by means of screw plugs, so that there is no waste. The electrodes are water-cooled. The furnace is lined with magnesite brick and crushed dolomite, while the roof, which is removable, is lined with silica brick. A spare roof is kept constantly in readiness, so that when the old roof is worn out it can be replaced without any delay. The arc between the electrodes and the bath can be regulated either by hand or by Thury automatic regulators. The usual practice when melting scrap is to use the hand regulators until the scrap is partly melted, when the automatic regulators are started. The case for these regulators is built into the wall between the engine-room and the foundry, so that they are accessible both to the melter in the foundry and the electrician in the engine-room. Fig. 2 shows a view of the regulators from the engine-room. The doors by means of which the melter can gain access to them can also be seen.

The furnace rests on a concrete foundation 2 ft. 6 in. above the level of the foundry floor. When skimming off the first or oxidising slag the middle part only of the platform is raised, and a shallow bogie is run in under the platform. When the slagging is finished this bogie is run out again. The bogie, when in position for receiving the slag, rests on a sliding platform, which is pushed back when the furnace is ready for tapping, thus allowing room for the ladle.

The method of working the furnace is that regularly employed when melting and refining scrap in a Héroult furnace. Iron ore, lime and scrap are charged into the furnace and the current turned on. When the scrap is all melted the slag is skimmed off, and a new slag consisting of powdered coke and lime is added. When a sufficiently high temperature has been obtained the furnace is tilted electrically, a motor of 5 h.p. being employed. The control of this tilting mechanism is placed immediately in front of the furnace. The scrap employed is a mixture of horse-shoes, casting and foundry scrap, boiler punchings, and miscellaneous heavy steel scrap of small dimensions.

The furnace is served by a 5-ton overhead electrically-driven crane, built by Messrs. Royce, of Man-

chester. Steel from the furnace is received in a 2-ton bottom-teeming ladle, the actual casting being performed through the intermediate use of hand shanks, and, in the case of the larger castings, by direct casting from the ladle. By the use of a bottom-teeming ladle a ready method is obtained of delivering small and intermittent quantities of steel, free from slag, both to shanks and moulds.

The steel made is, of course, exclusively dead soft, *i.e.*, between 0.1 and 0.15 per cent. carbon, with manganese and silicon varying slightly according to the special mechanical properties required. Owing to the refining powers of the electric furnace the sulphur and phosphorus are extremely low, being

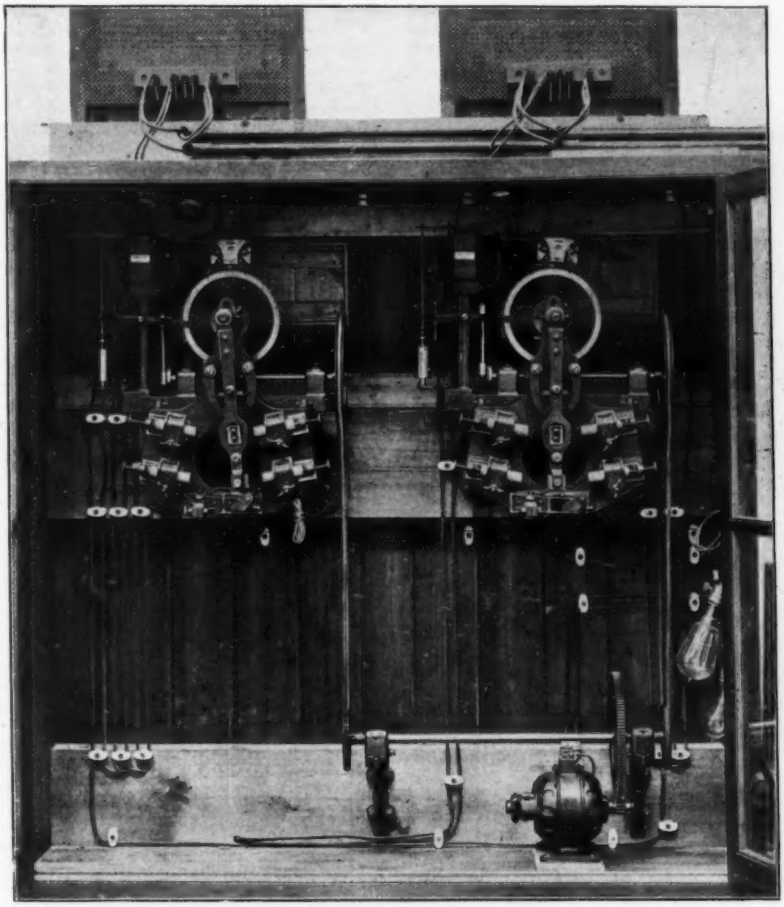

FIG. 2.—VIEW OF REGULATORS OF ELECTRIC FURNACE.

together less than 0.03 per cent. As a result of the absence of sulphur the proportion of cracked or torn castings is reduced to a minimum. Tearing is generally due to contraction of a casting over large surfaces. The shape, size, and condition of cores will frequently not permit the necessary shrinkage to take place, and this sets up stresses in the steel which are sufficient to cause rupture should the steel show any tendency to red-shortness, which is aggravated by the presence of sulphur. For case-hardening, the steel is quite equal to the best crucible steel of the same carbon contents.

## An Inquest on a Waster.

At a meeting of the Lancashire Branch of the British Foundrymen's Association held at the Manchester Municipal School of Technology, on Saturday, March 2, Mr. Penlington, President of the Branch, in the chair, a Paper was read by MR. J. SIMKISS (the Vice-President) on "An Inquest on a Large Shaper Bed."

The speaker, in opening, said he was about to deal with a subject with which all foundrymen were acquainted, and though the title might be somewhat peculiar, it was nevertheless very suitable. The particular incident actually took place recently in the foundry over which he presided, and he should give them his verdict concerning this waster casting. It was not a very strange or unusual occurrence to have a result from a mould which could not well be passed over the scales; in fact misfits occurred in the best regulated foundries, and under the most perfect management. It was from these cases that much experience was derived. Providing the man in charge was greatly interested in his work, and would not pass over losses without thorough investigation as to the real

cause, he would be able to guard himself against a similar weakness on a repeat order or similar work.

He had made several shaper beds at different periods, and in his opinion the job did not involve any serious risks as to the result. But he had a rude awakening in connection with a mould which to all appearances, and as far as skill in workmanship was concerned, was as perfect as it was possible to make it. He did not propose to deal minutely with the process of making the mould, but a few particulars were necessary. The job was made in the floor; two runners at each end, placed at the bottom of the bed, and one riser on each side made to flow off, constituted the arrangement for pouring. The pouring basins were built up somewhat, so as to well lift up the metal, which would add to the weight of the strain on the lower part of the mould. The mould being closed was weighted, and what was termed "weighted off," that was, planks were placed on each side of the mould longitudinally, bearers placed on

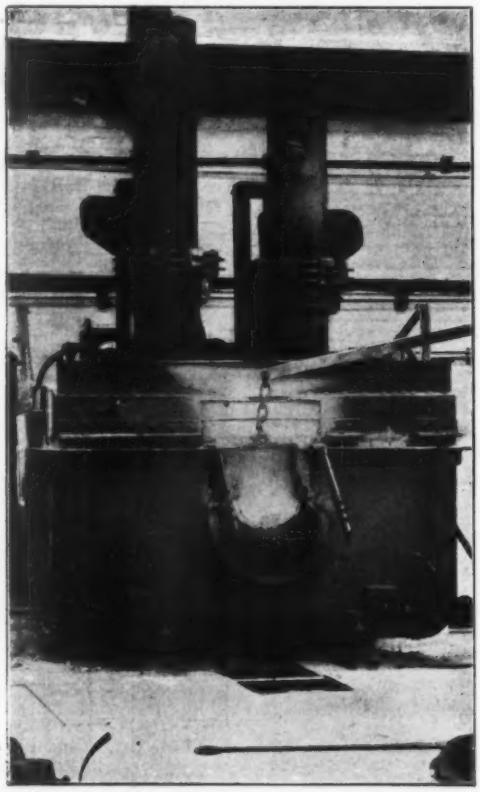

FIG. 3.—FRONT VIEW OF HEROULT FURNACE.

these across the top box and weighted, after which the box was cottered to bearers. The whole of the weights were on the outside of the mould to resist the strain, for there would naturally be a great side thrust on a mould of that shape, as well as the usual lifting strains. The method of weighting adopted served both purposes.

The dimensions of the bed approximately were 10 ft. by 4 ft. by 3 ft. 6 in., with three solid bars for tee slots running lengthways of the bed. The weight of the casting was 3 tons. The pattern was a block pattern, and 5 cores took out the inside, forming cross bars between each core, the cores cutting through top and bottom.

What happened on the occasion in question was this, a ladle having been placed at each end with a sufficiency of metal, pouring was begun, and the mould was rapidly filled. The risers were just coming up, when a crack was heard, and the molten iron having sank rapidly from the pouring basins, was as quickly belched forth like a couple of volcanos, back up the pouring gates. After it had settled down a short investigation was made, and proved that the bed pipe vent and all the core vents were in order.

On the day following he made a careful inquiry into the whole circumstance, and arrived at the conclusion he was about to state. Before doing so, however, it was necessary, to make the matter quite clear, to say a word on the situation of the foundry. The works were built on a rising ground, about 1 in 28, the front being on the street level. The extreme end of the shop, which was 340 ft. long, was on filled land to a depth of 12 ft.; the land continuing to rise in front of the works for some considerable distance. Part of the land was used as a tip for the works before it was covered by an extension of the buildings, and was composed of the used waste products of a foundry. The locality for some miles round was chiefly composed of sand which was found within a few feet of the surface, these few feet being a compost of soil and clay. The above details were needful in order to explain the conclusion to which he came as to the cause of the metal getting away. He further remarked that in taking out the hole to the depth required for the job, they were in close proximity to the natural earth level, and this being well rammed, the cinder bed was laid and prepared to receive the pattern.

In the month of January there was a very heavy rainfall, and he came to the conclusion that the water in draining from the higher ground through the sand on its way to several large wells in the locality, from which considerable quantities of water were pumped, had probably cleared a narrow space just below the earth, so that when the final strain from pouring came on, it pressed down the earth between the mould and sand, the metal quickly finding its way into the space thus left. It appeared to have struck down, then turned its course upward, driving into the soil and clay of the original level, and reached a distance of 5 ft. from the mould, forming a large shelf or irregular plate of iron, the full length of the bed. The cinder bed of the mould was intact and not in the least disturbed.

He was fully cognisant of the practice of plating or bricking the bottom of jobs of this kind, and some foundrymen might suggest it should have been done in the present instance, with a fair surface of core cutting through; but he deemed it unnecessary. The job was again quickly made and without mishap in the same hole, after taking out the old cinder bed and well ramming the ground below, which was soft but not wet.

MR. SIMKISS, in answering questions, said there would be no water whatever in the original earth level. The shelf of iron drove into earth that had not been previously disturbed. Below the natural earth level there was practically 40 ft. of sand. A good deal of pumping took place at a large farm about 300 yards from the works. About two years ago when making a large hydraulic casing standing about 7 ft. high, the bottom flange, instead of being 3 ft. by 6 ft. and two inches thick, was three inches thick as regularly as if it had been so intended.

MR. SUTCLIFFE remarked that that showed there was a leakage, or the plate would not have been pushed down an additional inch. Had it been rammed it would have been all right. He thought it was through the ramming having been neglected in the case of the shaper bed that the mischief arose. Had there been any extra pumping in the immediate neighbourhood about the time?

MR. SIMKISS replied that there might have been a great deal of water taken just before, and that would make a very considerable difference.

Mr. Kay thought the reason of the mishap was obvious. The mere fact that it went through the entire course of the bed, showed that something must have given way underneath. The insufficient ramming of the bed might have caused it, but in his opinion the ground must have subsided.

The Chairman, in closing the questions, remarked that in his opinion water was at the bottom of the trouble.

## THE SELECTION OF IRONS.

Mr. Cordingley (Newton-le-Willows) introduced the question of the "Selection of Irons for Certain Castings." He said that at one time the discussions concerning the moulding of large and small castings took place in the public house, and occasionally the "casting" fell out of the crane and put an end to the debate. Nowadays they had classes under Professor Rhead, but in the majority of cases lectures could only be explained by figures and results. For all that, however, he would strongly advise foremen, both young and old, to join the classes, in which they would find the theoretical and practical sides put together in the simplest manner possible.

He showed on the blackboard a diagram or scheme of figures as follows:—

| | D | L | E | S |
|---|---|---|---|---|
| Graphitic Carbon ... ... | 2.5 | 2.6 | 2.9 | 3.93 |
| Combined do. ... ... | 0.5 | 0.6 | 0.53 | 0.25 |
| Silicon ... ... ... ... | 1.8 | 1.4 | 2.83 | 2.85 |
| Sulphur ... ... ... | 0.08 to 0.15 | 0.8 | 0.075 | trace |
| Phosphorus ... ... ... | 0.56 to 0.75 | 0.56 | 0.996 | 0.911 |
| Manganese ... ... ... | 0.7 | 0.84 | 0.656 | 1.08 |
| | Tab. | Journal | Tab. | Journal |

Some of his hearers might say they could not gather much from the figures, but he could assure them the table had guided him many times in the selection of a mixture for a particular job. He was no chemist himself, and had to depend on fracture, and on the analyses given in the Foundry Trade Journal, and the table which was before them. To explain his selection of an iron for a particular job he would take a tank casting 4 ft. 6 in. square, 2 ft. 6 in. deep, and ¾ in. thick. Column E was suitable for a 12 ft. square tank; the high silicon 2.83 kept the metal fluid longer, and allowed the carbon to separate as graphite; high sulphur caused the iron to run sluggish; the sulphur must be kept as low as possible, as it increased the contraction; manganese in the present case had a corrective action on the sulphur; phosphorus rendered the metal more fusible and more fluid when molten; combined carbon hardened the iron (but high silicon and high graphite counteracted the hardening); graphitic carbon made the metal exceedingly soft and not so liable to crack.

For cylinders and high grade castings the cast iron must be close, hard and non-porous. Thus in column D, low silicon allowed the sulphur and manganese to harden the iron; high sulphur hardened the metal and tended to throw the graphitic carbon into the combined carbon, making the metal hard and white; manganese from 0.5 to 2 per cent. had the effect of making the metal close, hard and strong castings, non-porous; phosphorus entered into the iron with great readiness, making it more fusible; combined carbon increased the hardness and strength; graphitic carbon would not open out, but would be soft enough for machining.

Knowing what he required he could compare the figures on the tablet and the analyses of the British pig-irons. It was not a difficult task and they could easily pick out a brand from the analyses published in the Foundry Trade Journal, of August and October, 1907, January, 1908, and August, 1909.

## Moulding Sands.

No questions being asked, Mr. Cordingley introduced the subject of "Moulding Sands, their Composition, etc." He said the properties which should be found in a moulding sand were: (1) Plasticity, to adapt itself to the shape of a pattern; (2) cohesiveness or firmness, that it should not flow with the metal or it would produce dirty castings; (3) porosity so that gases could be got rid of in the mould, while to allow of contraction it must yield; (4) it must not fuse when in contact with the molten metal, in order that it might produce smooth castings.

The constituents of natural sand were as follows:—Silica, 89 to 93 per cent.; clay 6 to 8 per cent.; oxide of iron, ½ to 2½ per cent.; lime and manganese, ¾ per cent. Pure silica or rock crystal (quartz) was very refractory, and was only fusible in an oxy-hydrogen flame. Too large a percentage of silica in the sand would diminish its necessary cohesiveness. Again, good sand for moulding should not contain round grains but grains that were sharp, so that they would interlock. Alumina or clay, which had a cohesive or binding property, must not be present in too large a percentage, because it would cause the moulds to crack, owing to the shrinkage of the clay in drying. Further, it reduced the porosity so that horse dung or silica should be added. The binding power of a sand was not entirely due to the clay, but to the irregular or "sharp" formation of the grains. Silicate of lime and manganese should not exceed one per cent., or the result would be a sand-burnt casting, to prevent which coal dust might be added. The carbon of the coal with the oxygen of the air, at the high temperature of the mould, formed a gas, and the thin stratum of such gases largely prevented the direct contact of the metal with the sand. For small castings 6 per cent. to 7 per cent. of coal dust would suffice, while for large castings 8 per cent. to 10 per cent was required.

No questions were asked, and Mr. Cordingley brought forward the subject of "The Venting of Moulds and Cores," observing that bad castings had been obtained through the cinders being too near the top of the core. The air in the core being heated to 1,500 Centigrade increased to 5½ times its original volume, and to allow it to escape the cinders must be kept in the centre of the core, or the expansion of the air would break through the top of the core, disturbing the blacking and sand, and causing scabbed castings. The same remarks would apply in the case of a mould with a deep flange. Venting must be done upside the flange or the metal would boil, and scabbing would occur near the runner. Vents should be brought off well below the surface of the mould.

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## The Carnegie Gold Medal.

The Council of the Iron and Steel Institute have this year decided to award the Andrew Carnegie Gold Medal of the Institute to Dr. Paul Goerens, of Aachen. Dr. Goerens is a distinguished metallurgist and is a member of the staff of the Royal Technical College at that city. He has made many contributions to scientific metallurgy, and in 1910 he was awarded one of the Carnegie Scholarships of the Iron and Steel Institute, to enable him to pursue his investigations on the "Influence of Cold-working on the Properties of Iron and Steel." The Gold Medal is now awarded to him in recognition of the highly meritorious character of his research work on this subject, which was published last year in Vol. III. of the Carnegie Scholarship Memoirs of the Iron and Steel Institute.

# Steel Castings and the Effect of Heat Treatment.

Before the London Branch of the British Foundrymen's Association, on March 8, a lecture on "Steel Castings" was given by Mr. Hy. Brearley, research metallurgist in the Brown-Firth Research Laboratory, Sheffield. An extensive abstract of the lecture, which was illustrated with specimens and photo-micrographs, is given herewith:—

Steel cast in sand moulds and slowly cooled has a coarse structure of a highly crystalline kind. In commercial castings, a few tons or more in weight, a single crystal may measure quarter of an inch or more across, and it is frequently possible to separate the individual crystals from the mass, along their junction surfaces, without appreciably distorting them. The difference in the appearance of the fractured surfaces, before and after certain heat treatment, is very striking, as the heat-treated specimen would pass for a fair sample

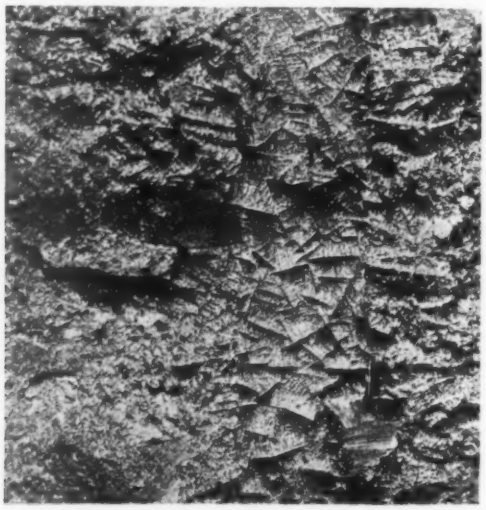

FIG. 1.

of well-forged or rolled material. The lecturer's main object is to discuss in brief outline the changes in structure and properties which take place between these two extremes.

In order to avoid criticism one should, perhaps, speak of a steel casting as an aggregation not of crystals, but of crystalline grains. Perfectly formed crystals in the mass of the material are certainly rare, but the interior surface of a shrinkage cavity or blowhole offers favourable conditions for the full growth of crystals. Fig. 1 represents the surface of a central cavity about 3 feet long and 1¾ inch in diameter. Although in the mass of material perfect freedom of growth is denied to a crystal as such, there is considerable freedom in the interior arrangements of its constituents according to its particular crystalline habit. These can, of course, only be observed in polished and etched micro-sections. The constituents are free during slow cooling from high temperatures to arrange themselves according to their disposition or habit. If a section made from an un-annealed mild steel casting is polished and etched, almost invariably a pattern of straight lines arranged parallel to the sides of an equilateral triangle is shown. This pattern is naturally more or less disturbed by rapid cooling, and may be obliterated altogether by casting in small chill moulds. It may be taken, however, for general purposes, that the triangular structure shown in Fig. 2 is the characteristic structure of a mild steel casting, the large patches of free ferrite being due, in most cases, to the unavoidable presence of small globules of slag around which the free ferrite collects as it falls out of solution.

It is generally believed, and rightly, that a steel casting is less reliable before than after annealing. The drop test which is applied to wheel centres and many forms of marine castings, is the usual means adopted of excluding brittle objects from service.

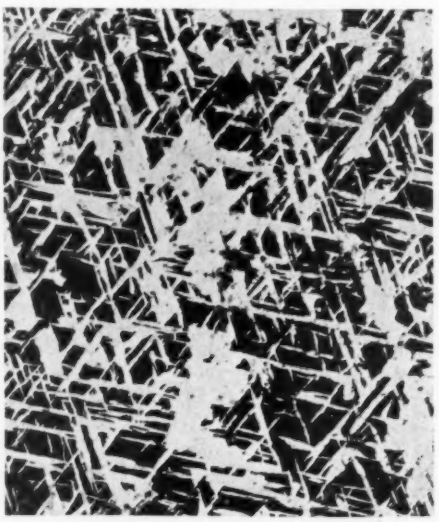

FIG. 2.

The pendulum hammer impact testing machine is, however, the simplest method for investigation purposes. For unannealed castings the author has used a bar 10 by 15 mm., provided with a circular notch of 1 mm. radius lying 1 mm. below surface, so that the area of the material to be fractured by the impact blow is 120 square millimetres.

From what has already been said regarding the structure of unannealed steel castings, it might be predicted that their fragility as measured by the impact test would be a very uncertain quantity, and so it is. In Fig. 3 is shown a representation of a notched bar after polishing and etching. According to the manner and rate of cooling the crystals may be approximate spheres or very much elongated ovals. When slowly cooled a single crystal may measure 10 mm. across, and it obviously makes a very great difference whether the notch falls on the junction line or on either side quite clear of it. In the latter case the impact figure might be three or even four times greater than in the former case.

When impact pieces have been notched, polished, and etched, it is possible from the structure of the material lying immediately behind the notch to predict with some degree of certainty the resistance which the test piece will offer to the impact blow. The fracture due to impact travels readily along lines of weakness lying in the same plane, but is distinctly hindered by blow-holes or even cracks, which lie at right angles to the impact blow. The irregular results will, therefore, depend to some extent also on whether or not the well-defined cell walls of ferrite fall behind the impact notch in a direction vertical or parallel to the impact blow.

The fact that the pattern of interlacing triangular lines seen on a plane section occurs in unannealed castings and that unannealed castings are apt to be brittle, has led some persons to the conclusion that the triangular structure is both weak and unreliable. It resembles, however, to some extent certain engineering triumphs which are supposed to be remarkably strong, and it suggests nothing from a geometrical or engineering point of view which is, that the author knows of, seriously objectionable. What is objectionable about the pattern so far as mild steel is concerned, is that it implies slow cooling

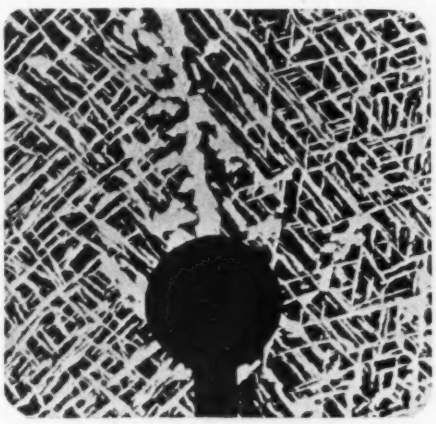

Fig. 3.

from high temperatures, and this necessarily means that the crystalline grains are relatively coarse, and allow a crack to travel between them on that account with greater readiness.

If, however, we compare one type of structure with another, we find the most fragile pattern to be that shown by Fig. 4. In thirteen tests the impact figure obtained varied between 8 and 16 foot pounds; all uniformly low because no matter where the notch happened to fall, intercrystalline lines of weakness were lying immediately behind it. On the other hand, when the crystalline grains were larger, but possessed the well-marked triangular structure, the impact figures for material of like chemical composition varied between 25 and 65 foot pounds; being higher or lower according to the position of the intercrystalline junctions in relation to the notch. Where the structural pattern in two steel is similar, the one bearing the larger pattern is the weaker. It is clear, of course, that in these tests, as in every other, the occurrence of small gas or shrinkage cavities, or of occluded slag embedded in a ferrite envelope, lead all to erratic results. These notwithstanding, a fragility test of the kind mentioned is an exceedingly valuable index of the quality of a steel casting.

Professor Bradley Stoughton, of America, recently said, "The annealing of steel castings is not always a necessary operation, and especially in the manufacture of small steel castings which have not great length to produce severe strains by shrinkage." The mischievous nature of this statement can be exhibited in two or three ways. For the sake of simplicity we may leave the question of shrinkage entirely out of account in showing the purpose and advantage of annealing.

By annealing I mean the reheating of steel castings after they are taken from the sand, followed by more or less slow cooling. If the castings are heated only to low redness the typical structure of Fig. 2 is only partially obliterated. The shrinkage stresses are relieved, but the crystalline grains are little, if any, smaller, and their internal structure still bears some resemblance to its former self (see Fig. 5). The most important purpose of the annealing operation should be to break down entirely the large intercrystalline boundaries and then permit the material to reform new crystalline outlines under more favourable conditions during the subsequent cooling. After this treatment the material, so far as structure alone is concerned, may be compared with an overheated forging. The very coarse crystalline

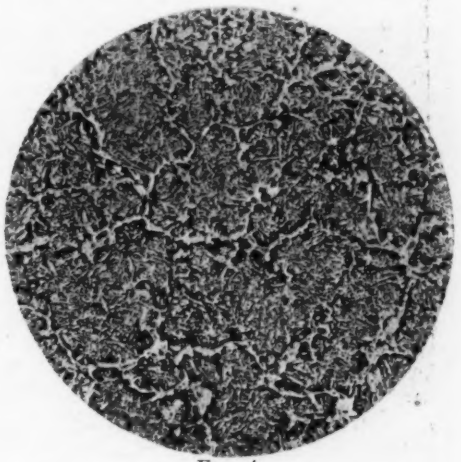

Fig. 4.

structure has disappeared, fragility tests give high and quite concordant results, and the fractured surface is no longer to be distinguished in appearance from that of a cogged billet.

Annealing is also desirable for another reason quite independent of shrinkage stresses. The interior surface of a sand mould generally contains carbonaceous matter either in the moulding composition or as black-lead paint, or in some other form. This, or the gas evolved from it, comes into contact with the hot steel over the entire casting. This is a serious matter, at least so far as corners are concerned, because the cementing action is most marked in those places from which cracks can most easily be started. This feature is not avoided in those processes of making castings which are said not to require annealing. Fig. 6 represents the outer edge of such a casting, and whereas in bulk the material contains less than 0.3 per cent. carbon, the material on the extreme surface contains approximately 1.5 per cent., and is on that account considerable less reliable than it might otherwise have been made by proper annealing.

The hard outer envelope on an unannealed casting may have some commercial value as a wearing surface where the shape is extremely simple and the

stresses to be resisted are very low; but it is chiefly useful from a laboratory point of view as an indication that the casting has not been annealed. This distinction and the etched structures which can generally be observed with a hand lens are almost conclusive evidence.

During the many hours that the casting is exposed at high temperatures to the oxidising atmosphere of an annealing furnace the carburised envelope disappears, and instead is got an envelope of carbonless metal, accompanied, of course, by a re-arrangement of the internal crystalline structure. Here again we have a simple means of deciding whether or not a particular casting has been annealed. The structure alone, however, is not an infallible guide, because after being exposed to very high temperatures the triangular pattern reappears, and reliance must be placed, amongst other things, on the carbonless envelope, and especially on its unusual thickness as an indication that the casting has been through the annealing process.

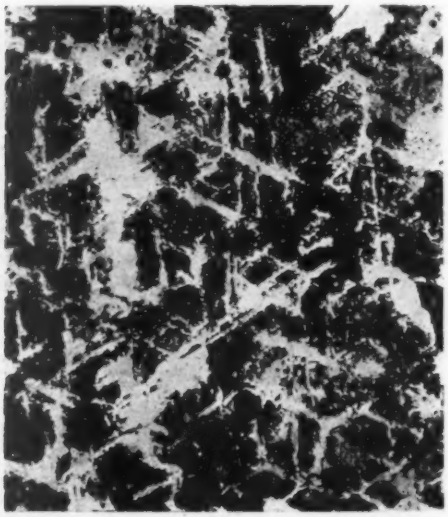

FIG. 5.

There is sometimes considerable doubt as to whether castings of delicate structure and complex outline can be kept to shape at the high temperature necessary to break down the coarse primary structure. Difficulties of this kind must be dealt with separately as they occur. There are, however, sometimes hindrances in the steel itself of a very serious nature which cannot, according to certain authorities, be overcome by any mode of heat treatment at present known. The author refers to the presence in special forms of non-metallic impurities, which may be grouped under the head of slag inclusions. No treatment whatever, for example, would remove the local defect exhibited by Fig. 7. In the mass of a casting such areas here and there might not be very serious, in fact, few large castings, or forgings either for that matter, are entirely free from these blemishes. If, however, material of this kind happens to form part of a tensile or bend test-piece, it spoils the results absolutely.

But more serious than the segregated slag area, because more elusive and more widespread, is the tendency under certain conditions for envelopes of non-metallic impurities to form about the crystalline grains. These always weaken intercrystalline cohesion and are most difficult to deal with. A slag globule within the primary crystal itself is comparatively harmless. When, for some reason, the slag falls as films between the grains, it is not easy to set a limit to the troubles which may follow. A very slight disposition to pull is satisfied immediately by the formation of a crack as seen in Fig. 8.

It is said that films, or silico-sulphide streaks as they are sometimes called, will ball up on annealing. But the examples the author has seen are unfortunately not of that variety, and he seriously doubts whether the balling up of an actual film has ever been accomplished by any form of heat treatment a steel casting might be expected to survive. Having located themselves between the primary crystals the films persist as films. As often as the casting may be heated up they are there during the subsequent cooling acting as nuclei and gathering about themselves the free ferrite as it falls out of solution. The fact that the free ferrite gathers about them is possibly of no greater consequence than that it enables them to be at once located on an etched surface; the real mischief is that the continuity of the material is imperfect, and resistance to any form of stress—particularly shock stresses—is very low. It is bad enough to have to

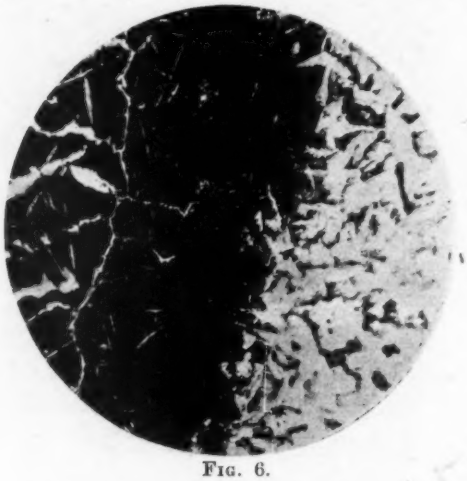

FIG. 6.

put up with such blemishes where no cure is known, and the means of controlling their appearance are imperfect. But it is surprising to find certain kinds of alloys advertised for steel-making purposes, whose most striking feature is the formation of brittle envelopes around the primary crystals. The commercial alloys of tantalum belong to this category. But more marked even than tantalum is the embrittling effect of very small quantities of boron. Fig. 9 represents a steel as cast, which contains about 0.2 per cent. of boron. The boride or carbonboride of iron, or whatever combination it may exist as, is clearly visible. Two-hundredths per cent. of boron would also form visible films. No form of heat treatment which could be applied to a steel casting is able to eliminate the brittleness or even to usefully minimise it. Even when hardened from 1,200 to 1,300 deg. C. the brittle envelopes still persist.

Every large casting, whether of steel or iron, contains somewhere inside it shrinkage cavities of greater or less dimensions. This is no reflection on the founder's skill, but a plain statement of fact which must be taken into consideration if we are to understand properly the dangers of pulling and clinking.

It would generally be conceded that metal poured slowly into a cast-iron mould with straight sides had a favourable opportunity of solidifying without any shrinkage cavities—apart from the pipe—being formed. Most of the tool steel made is cast into such moulds whose diameter varies between 3 in. and 4½ in., and for various reasons, the top ends of these small ingots are sometimes broken off piece by piece until nothing remains. I know of no operation in the whole of iron and steel founding where an observer has better opportunities of looking inside the objects cast. What such an observer finds, not occasionally, but almost invariably is that in the centre there are very small cavities. Below the bottom of the pipe the area exposed appears perfectly sound. Then, a further piece being broken off, a small cavity becomes visible. After that several pieces may be broken off before another small cavity appears, and so on until the ingot is entirely broken up.

These small cavities are frequently the seat of origin of clinks both during the cooling down and heating up of steel objects. Their occurrence is not entirely avoidable, no matter how a casting may be fed, for the simple reason that shrinkage takes place in the material when the metal has ceased to be sufficiently fluid to run into the cavities and fill them up.

In a rolling mill handling either steel, brass, bronze, German silver, or any metal whatsoever, one frequently sees flat bars and sheets which are split on the ends and forked 5, 10 or even 20 per cent. of their length. Such material is cropped off as waste. The cause of the forking is what the foundryman calls pulling. It would seem an easy matter to avoid a defect of this kind in the simplest form of chilled casting. But the closed bottom of a split ingot mould becomes roughened or pitted by use, and on this account, or through avoidable carelessness, the ingot fastens itself in some two or more places on the bottom of the ingot mould, and cannot shrink transversely during the subsequent cooling. The consequence is that small cracks are formed across the bottom of the ingot which are so nearly invisible that they are almost invariably overlooked.

If at two places a considerable distance apart the shrinkage of a casting is prevented, the pull is too obvious to be overlooked; indeed, one may sometimes get some light through the crack on to the ruptured faces, and notice the very coarse needle-like structure which too hastily is taken as an indication that the metal was cast too hot. Neglecting, however, those cases of pulling due to shrinkage and normal contraction, the author will consider more fully the possibility of pulling due to critical expansion.

During the heating of a piece of steel at a uniform rate, say, 1 deg. Centigrade per second, there is reached a range of temperature in which the heating of the steel is seriously retarded, although the surrounding furnace gets hotter at the same rate as before; and, during subsequent cooling at the same rate, the steel over a certain period ceases to cool, or may even become hotter, although the temperature of the surroundings continues to drop at a uniform rate. This fact is well known. On the same assumption the piece of steel during the heating will gradually increase in length until the same particular temperature is reached, when it will actually contract; and inversely on cooling in the course of the general contraction the steel will momentarily expand.

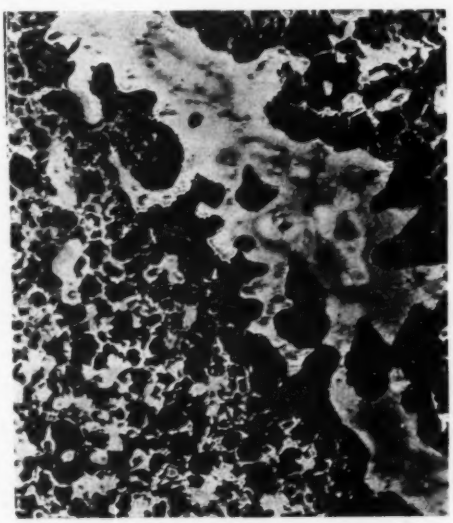

Fig 7.

Fig 8.

We have here the simplest possible case, and it is quite obvious that during cooling the thinner sections of a casting will pass through the range of critical expansion first and have to bear later an inevitable stress when the same change is being passed through in the thicker sections. But the danger of pulling is still further increased by certain variations, depending on the initial temperature and the relative rate of cooling, which are closely associated with special alloy steels. They are, however, worthy of mentioning because not only alloy steel, but alloy irons are also now being used in the form of sand castings, and will become still more extensively used when more experience in the handling of them has been accumulated.

Consider first the series of curves reproduced in

Fig. 10, and note that when the material is heated to 820, 870, or 900 deg. C. the critical change on cooling occurs at about 700 deg. C. Under the prevailing experimental conditions it occurs always at 700 deg. C., so long as the maximum temperature reached on heating does not exceed 900 deg. C. But on cooling from 925, 960, 1,050, or, indeed, any other temperature above 925 deg. C. the critical change occurs at about 400 deg. C. This variation depending on the maximum temperature always repeats itself if the time taken in cooling does not exceed one hour.

On the other hand, another steel of the same group, from whatever temperature cooled, passes through the critical range at a temperature of about 300 deg. C. if the rate of cooling exceeds 300 deg. C. per hour, but if the rate of cooling is less than 100 deg. C. per hour, the critical change occurs at about 650 deg. C.

Take a third case of a comparatively simple steel containing nothing unusual except about 1.5 per cent. of chromium. When cooled from about 820 deg. C., the critical thermal and expansion

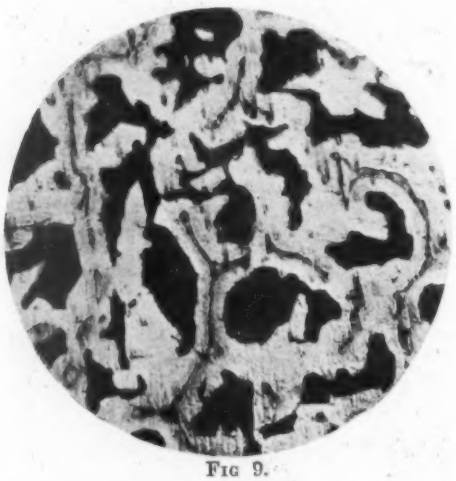

Fig 9.

changes occur at 710 deg. C. But as the temperature to which the steel is heated become successively higher, the critical range on cooling appears at lower and still lower temperatures; but when it does occur the temperature swings back again to the normal figure of 710 deg. C. This property of metals is very much akin to what is called surfusion in liquids.

In the critical cooling range something is falling out of solution; the tendency to fall out becomes less as the maximum heating temperature is increased, and finally the steel can be cooled to atmospheric temperatures without exhibiting any critical change at all and without allowing anything to fall out of solution. Under those circumstances the steel remains hard.

In summarising the critical expansion changes which accompany thermal changes of this erratic nature, it is in the first place quite obvious that volume changes may be taking place in different parts of the same casting at different times, not only during the setting of the metal but in ranges of temperature down to 300 deg. C.; and also that such changes in special steels at least will depend on the rate of cooling. In the subsequent treatment of steel castings there will be the same difficulties in the cooling and the added difficulty depending on variations is the maximum temperature to which different parts of the same casting may be exposed. But there is every reason to believe that with intelligent care and close observation they can be overcome.

### Discussion.

Mr. J. Horne, in seconding a vote of thanks, proposed by the President, remarked that he did not see that all steel works could be expected to possess laboratories. They were not all so prosperous and up-to-date as the one the lecturer was connected with. He did not see why steel-makers any more than makers of brass, etc., should possess them.

Mr. Nash asked if carbon was not absorbed from the mould itself?

Mr. Calder did not quite agree with the lecturer's remarks on microscopical investigation of steel fractures. The lecturer had mentioned that low magnification was to be preferred to high, but it seemed to him (the speaker) that was by no means the case. If the low magnification of a steel fracture was increased to six times the magnification, the results were very different.

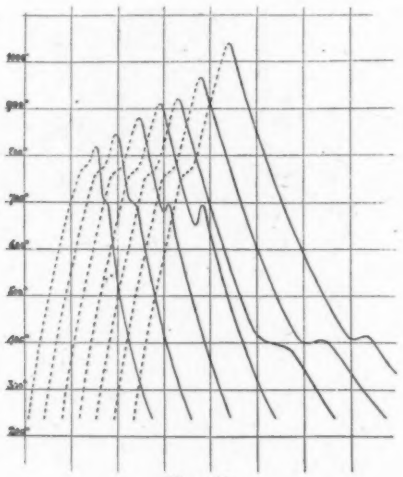

Fig 10.

Mr. Boot expressed doubt as to the reliability of the impact test by the pendulum hammer.

Mr. Woof asked why it should be absolutely necessary to anneal steel castings? He knew of many firms making steel castings without annealing, although, as he sarcastically remarked, they appeared to take just the same time to produce the casting.

Mr. Brearley, in answer to Mr. Calder, said it was very instructive to examine sections at magnifications of not more than 3 or 4 diameters, as this brought the object very near to that seen by the naked eye. With regard to Mr. Nash's question, he (Mr. Brearley) thought the carbon was absorbed from the blacking used for facing the mould. Carbon on the surface would be very apt to lead to cracks. As regards another member's question, it was sometimes possible to give a mechanical test to meet a specification before annealing. He had no doubt at all that it was absolutely necessary to anneal in order to avoid fragility. Mr. Boot had expressed doubt as to the reliability of the impact test. He could testify to the method of a pendulum hammer being an excellent one, and the results therefrom quite reliable when properly interpreted.

# Casting Steel and Alloys in a Vacuum.

By E. F. Lake.

While casting metals *in vacuo* is an old principle, it has not been developed to any extent until quite recently. Occluded gases and those segregated in large enough volumes to form miniature bubbles or the larger blowholes, are only beginning to be recognised as the real injurious elements in metals of all kinds. The oxygen, nitrogen, and other elements that form these gases, enter into combination with the elements that are parts of the various alloys from which castings are made, and form oxides, nitrides, etc., and thus detrimentally affect the strength, wearing qualities, and other properties that it is desirous to obtain in the various metal parts that are manufactured. By melting and casting metals in a vacuum, these gases can be almost entirely removed and the mechanical properties of metals or alloys greatly improved. This principle is fast growing in favour, and, therefore, it may not be very long before casting in a vacuum will be quite common.

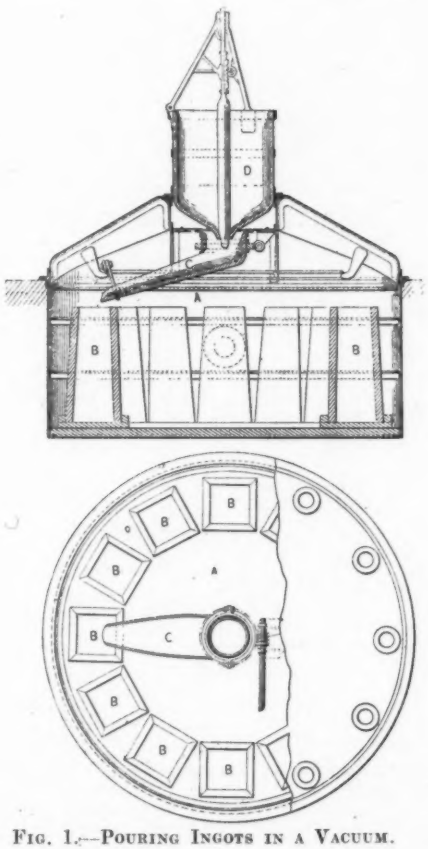


Fig. 1.—Pouring Ingots in a Vacuum.

A vacuum in connection with melting metals has been used to some extent with very good results. Some metals are very brittle substances, and when worked by ordinary methods, cannot be rolled and drawn. When melted in a vacuum, however, they have been drawn into wire for various purposes. Examples of such metals are tungsten and tantalum, which are made into wire for incandescent lamps. Another metal that is very difficult to melt in the open air is magnesium, and this has been readily melted in a vacuum furnace. This is accomplished by building an air-tight chamber around the melting pot or furnace and pumping out all the air. An electric current then generates the heat necessary for melting the metal, and no oxidisation can take place, as the oxygen has been removed, likewise the nitrides, sulphides, phosphides, etc., do not form, and the metal has a more dense, homogeneous grain than can be given it by any other process. No oxidising effect can, therefore, be given the metal when a good vacuum is obtained and the reducing effect of the atmosphere in the furnace is very slight, even at the highest temperatures.

Even though the principle of casting *in vacuo* is very old, the first recorded invention of apparatus for this purpose was that patented by H. V. Barnum, in 1879, as shown in Fig. 2. Here is a vacuum chamber with a door B through which any kind of a mould can be inserted. This door covers the whole end of the vacuum chamber. A clay-lined pot D of molten metal is fastened to the top of the vacuum chamber in such a way that no air will be admitted, and when the mould is ready to pour, valve E, which is made of some refractory material, is raised by lever G out of valve seat F, which is also made of refractory material, and this allows the molten metal to flow from pot D through spout C and into the mould. Spout C is made fan-shaped so the vacuum may cause the escape of most of the gases out of the molten metal as it flows over the surface.

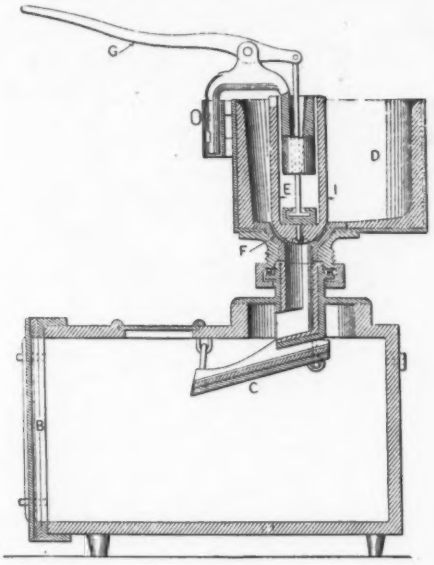


Fig 2.—Apparatus for Pouring a Mould in a Vacuum.

* Abstract from "Iron Age."

### Casting Steel Ingots in a Vacuum.

Practically this same principle is used for casting steel ingots by the Ellis May Steel Syndicate, Limited, of England. This apparatus is shown in Fig. 1. The vacuum chamber A is sunk below the floor line, and holds 12 ingot moulds B placed in a circle. The ladle of molten metal D is brought to the vacuum chamber and located in the centre of the cover over spout C. The apparatus is arranged so that when ladle D is dropped into position it makes the vacuum chamber air-tight, and the air is then pumped out of vacuum chamber A. When this has been done the spout underneath the ladle is made to revolve from one ingot mould to another until all have been poured. While the metal is flowing through the spout, any gases that may be in the molten metal are supposed to escape. It is said the pipe is thus considerably reduced.

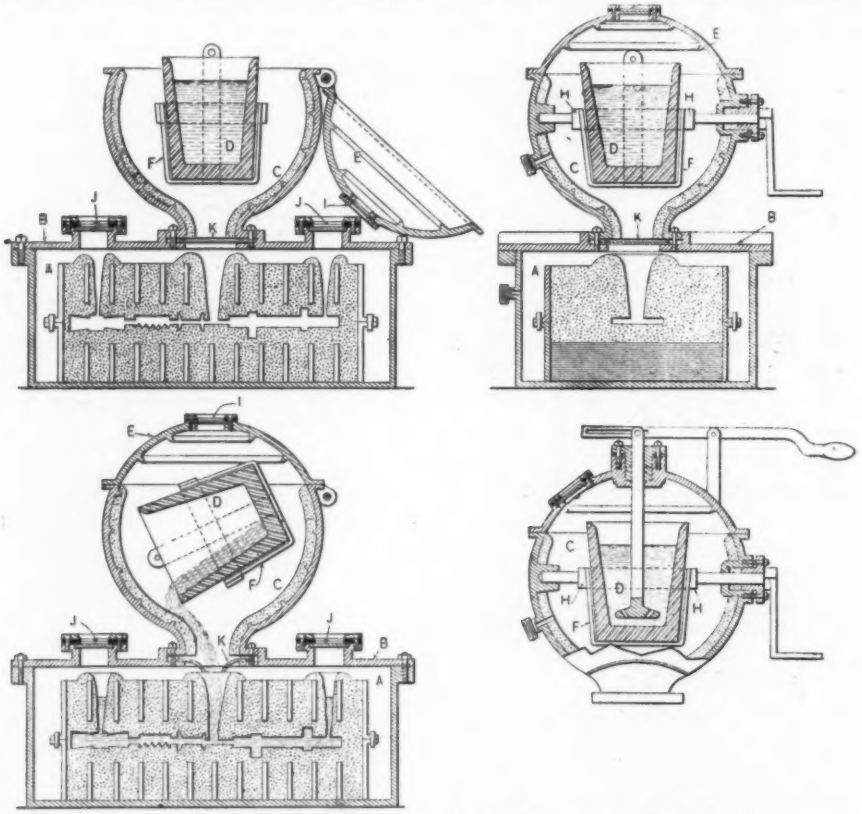


FIG 3.—EQUIPMENT FOR POURING SAND MOULDS IN A VACUUM.

### Casting Sand Moulds in a Vacuum.

Another apparatus for casting sand moulds *in vacuo* was brought out in 1893; its construction and method of operating are shown in Fig. 3. In this, A is the vacuum chamber; B the top which lifts off to admit the mould; C the ladle container, which is also a vacuum chamber, and D the ladle. To operate it, cover E is swung back, as shown in the upper left-hand view, while the ladle of molten metal is lowered into its holder F. The cover E is then swung over the top and it fits air-tight, as shown in the other views. When the air has been exhausted from chambers A and C, ladle D is turned over on its trunnions H H, and pours the molten metal into the mould. In the ladle cover at I and in the top of the mould chamber at J J, are located glass plates, so the operator can see how the ladle is working and when the mould has been filled.

By pouring moulds in a vacuum chamber in this manner, the metal more readily flows to all corners of the cavity, filling all interstices, and thus producing sharp, clean castings. The vacuum proves a stronger attraction, so to speak, than the molten metal for oxygen, nitrogen, and other gases, and hence as the metal is being poured into the mould, most of the gases are drawn out of the metal. This overcomes any tendency toward the formation in the castings of blowholes, gas bubbles, air pockets, cold shuts, and like imperfections, and the losses from bad castings are greatly reduced.

While exhausting the air from vacuum chambers A and C, the gases and vapours rising from the molten metal are carried away, and this renders the metal dead by removing all tendencies toward ebullition. By removing the gases from the metal, a more dense and fine grain is given the castings, and as the molecules that form the mass are not separated by these gases they are held together with a great cohesive force. Thus, vacuum castings excel ordinary castings by having greater strength, wearing qualities, and other mechanical properties, and by being more homogeneous, soft, and ductile.

If desired, an attachment could be easily put on cover E by which the metal in the mould may be stirred by a disc, located on the end of a bar passing

through the centre of the cover and attached to a lever on the outside. Such an arrangement is shown in the lower right-hand view of Fig. 3. It would hasten the pouring, as the ladle is turned over as soon as the gases cease to rise from the molten metal. Stirring would bring all parts of the molten metal subject to the vacuum condition, and thus quicken the escape of the gases. To facilitate this, a fusible plate is located at K to separate the ladle chamber from the mould chamber. Thus, the air can be exhausted from each separately, and the gases drawn away from the ladle without interfering with the mould. As soon as the molten metal strikes this plate it melts and allows the metal to flow through, as shown in the lower left-hand view.

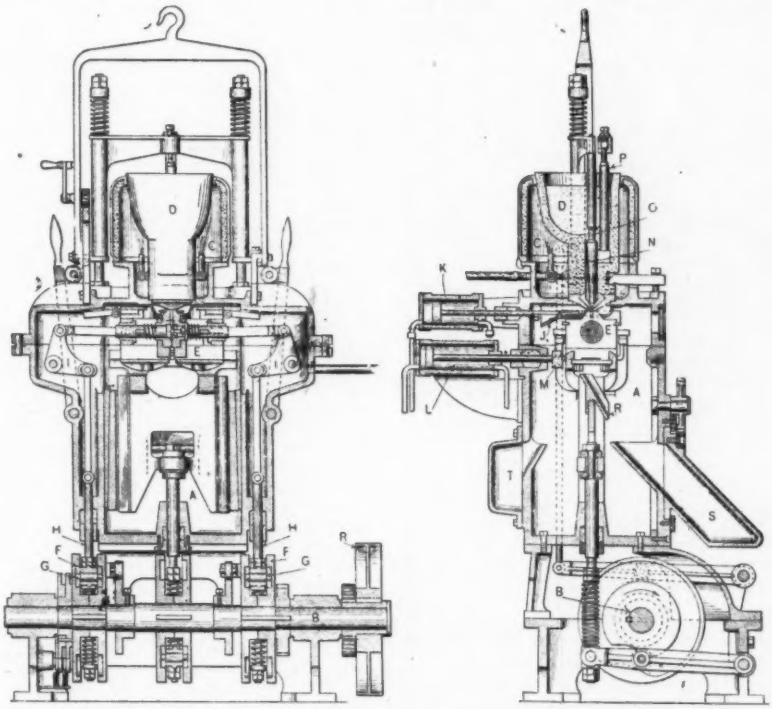


FIG 4.—MACHINE WITH VACUUM CHAMBER IN WHICH THE DIE-MOULD OPERATES AUTOMATICALLY.

### Application of Vacuum to Die-Casting.

The most successful and largest application of the principle of casting in vacuum is in connection with the manufacture of die-casting. As permanent moulds that are made of metal are used to give the castings their shape, a vacuum can be established in their cavity without using a vacuum chamber, or the die-mould can be located inside of a vacuum chamber without specially constructing the mould, fear of injuring it, or altering its ability to make perfect castings. They can be made to operate automatically either inside or outside of a vacuum chamber, and very little additional apparatus is required on the die-casting machines. The vacuum overcomes faults that are very difficult to get rid of in any other way when squirting molten metal into metal moulds under pressure.

When this is done in the presence of air, the continual churning that the die-casting alloy gets, both in the melting pot and when being squirted into the mould, causes it to absorb more or less of the oxygen, nitrogen, or other gases in the air, and generally it is more. These gases form compounds with the various metals composing die-casting alloys which greatly weaken them, and they also tend to fill them with gas bubbles and occluding gases. These bubbles usually form in the interior of die-castings, and make it spongy and porous, while the exterior may be smooth and have a perfect appearance. This is due to the fact that the molten metal squirted into the mould has a tendency to cling to the metal surface in the cavity that forms the outer surface of the castings.

The large majority of die-castings that are made outside of a vacuum are of this nature, and one has but to break them open to see these miniature blow-holes or gas bubbles. They can very plainly be seen with the aid of an ordinary magnifying glass. When these are present, it means that some of the molecules that form the mass are separated by the gases and their inherent cohesive force is interrupted. Thus the mechanical strength is entirely destroyed at this point. This, together with the injurious compounds that are formed with the metals, has conclusively proved that such gases as oxygen, nitrogen, and hydrogen are the most injurious elements that can be present in metals, and it is, therefore, imperative that these should be reduced to the very smallest percentages if castings are to be made that have any strength properties.

To establish a condition of vacuum when manufacturing die-castings, several forms of machines attach piping directly to the casting cavity in the die-moulds and connect this piping to an air pump. This removes the air from the mould just before squirting in the molten metal. This ensures that every corner and crevice in the die-mould is com-

pletely filled with molten metal, and good sharp castings with perfect exteriors are obtained. The losses from bad castings are also reduced to a minimum, as air pockets do not form to prevent the molten metal from flowing to certain parts of the mould.

While the extraction of the air from the die-mould has many good features, it is not possible to extract any of the gases that may be contained in the molten metal. In order to obtain a more complete vacuum, therefore, a die-casting machine like the vertical one shown in Fig. 4 was designed, and this is in daily use. Here a comparatively large vacuum chamber A forms the body of the machine, and the melting pot D, with its gas-heating furnace C, is located over it in a very similar manner to that of the sand mould casting apparatus shown in Fig. 2, and the ingot-casting apparatus shown in Fig. 1. In this case the

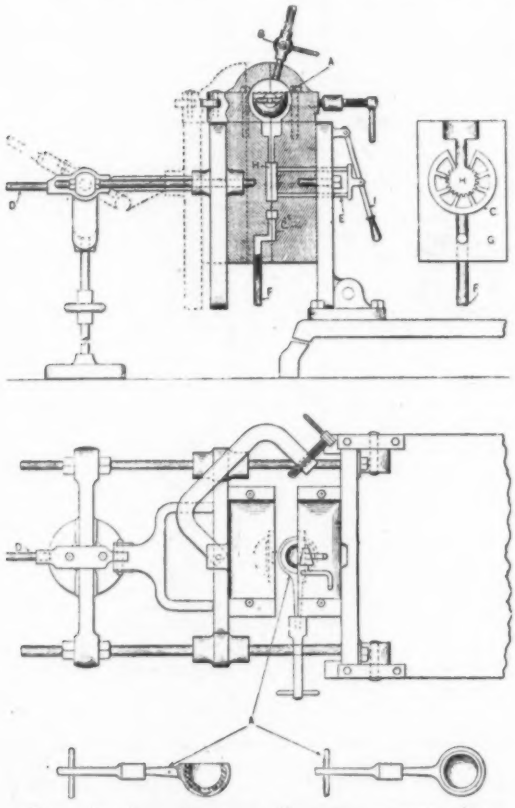

FIG. 5.—AIR SUCTION COMBINED WITH AIR COMPRESSION IN DIE CASTING.

driving shaft B, with its pulley R, and the cams that control the movements of the machine, are located in the base, below the vacuum chamber.

The die-mould E is located just below the melting pot and inside vacuum chamber A. To make such a machine successful, therefore, the mould must be opened and closed; the molten metal squirted in, and the casting ejected from the mould automatically, and that is the manner in which this machine operates. The mould opening and closing automatically inside of this vacuum chamber, no air is allowed to collect in the casting cavity, even when the mould is opened to eject the casting. Any gases that may be in the metal when entering the die-mould are inclined to be drawn through the vent openings of the mould and out into the vacuum chamber. By milling out sections, one or two thousandths of an inch deep, on the parting surfaces of the mould the mould will be vented, so a continuous vacuum can be maintained in its casting cavity. The mould is then easily parted, and these vent openings are not large enough to fill with metal and form fins on the castings. In addition to causing the metal to be drawn into all crevices of the mould, the molten metal is forced into the mould with from 80 lbs. to 100 lbs. per sq. in. pressure. This tends still further to refine the grain of the castings.

In the left-hand view of Fig. 4, the mould is shown closed; but when the double cams F turn over rollers G on rods H operate levers I, and thus pull the halves of the die-mould apart. As there is always a tendency of molten metal dripping when the die-mould is pulled away or parted, a drip deflector J is immediately pushed under the nozzle and causes any drippings to fall into pocket T. This prevents molten metal from spoiling the finished castings. A second air cylinder L moves brush M over to brush out the casting cavity in the die-mould. To force the metal into the mould when it is closed, valve N is pulled away from its seat in the nozzle opening, and this closes another seat above it at O, where the metal enters the passage from the melting pot. When opening O is closed, plunger P is forced down, and this squirts the metal contained in the passage into the die-mould.

All of these motions are timed so that the various operations will follow each other continuously and manufacture castings without any manual labour except that of filling the melting pot. They are turned out by this vacuum machine much faster than they can be made by any hand-operated machine. In fact, as fast as the metal will solidify in the mould, the casting is thrown out, and the mould closed for another without any lost time. As the mould is opened and the castings ejected, they fall into deflector spout R, which throws them into pocket S, and they are then easily taken away from the machine.

Still another form of die-casting machine that removes the air from the mould before filling it with molten metal is shown in Fig. 5. This is a hand-operated machine connected to an air pipe at F. It does not produce such good castings as the machine shown in Fig. 4, but is being successfully used in the manufacture of die-castings. The two halves of the mould are drawn apart by raising lever D. Then a ladle, like that shown at A, is filled with metal at an ordinary melting furnace and placed inside of a cavity above the die-mould. Lever D is then brought down to close the mould. After that, a valve is opened that takes the air from the mould through outlet C and pipe F, and the ladle full of metal is then turned upside down. Compressed air is next turned on by opening valve B and the metal that has been dumped out of ladle A is forced into the casting cavity at H by this incoming current of air. The mould is then opened and lever I is pushed in to force the casting out of the mould, with ejector rods E. This is the only machine that uses suction to draw the air out in combination with compression to force the metal into the mould. As this machine is only hand-operated, it is comparatively slow.

With any of these die-casting machines, it is not possible to cast metals having a melting point that is over 1,200 deg. Fah. This is largely due to the fact that no metal or material has been found that will withstand the action of any higher temperature and at the same time have wearing qualities that will enable one die-mould to make enough castings to be commercially successful.

# The Microscopic Structure of Brass and Bronze.

By O. F. Hudson, M.Sc.

At a meeting of the Birmingham Branch of the British Foundrymen's Association, held on Saturday, February 24th, an illustrated lecture was given by Mr. O. F. Hudson, M.Sc., A.R.C.Sc. (Birmingham University), on "The Microscopic Structure of Brass and Bronze."

The lecturer gave a short survey of the existing knowledge of the constitution of brass and bronze alloys, and explained that the constitution of a series of alloys was summarised graphically in an equilibrium diagram in which was represented the phase relationship throughout the series at any temperature when the alloys were in a state of true equilibrium. Equilibrium diagrams had now been published for the majority of the series of binary alloys, and most of them were approximately, or at least partially, correct. There were, however, very few, if any, diagrams which were quite complete, and in numerous instances further research had led to the introduction of more or less important modifications. Having traced the history of the equilibrium diagrams of the copper-zinc series from Roberts Austen's incomplete diagram published in 1897, the lecturer explained the diagram published in 1904 by Shepherd, which he said, had been generally accepted as complete and correct as far as concerned the copper end of the series, including all the yellow alloys. The condition of alloys of different combinations, slowly cooled or quenched at certain temperatures, was illustrated by means of micrographs, the first portion of the lecture dealing mainly with matters treated by the lecturer in the Paper read by him at the British Foundrymen's Annual Convention, in Manchester, in August, 1910.

Proceeding to deal with the work that had been done on the bronzes, the lecturer said that the copper-tin series was even more complicated than the copper-zinc, and there were still parts of the diagram which were incomplete or uncertain, in spite of recent modifications of Heycock and Nevill, a well-known diagram by Shepherd and Blough, and Giollitti and Tavanti. Considering only the copper end of the series from about 75 per cent. of copper upwards, it would be seen that the solid solubility of tin in copper in the $\alpha$ phase was less than that of zinc, the maximum being about 12 per cent. Between 9 and 22½ per cent. of tin the alloys solidified by the crystallisation first of $\alpha$ which, at a temperature of 780 C., reacted with the still liquid portion to give crystals of $\beta$ containing 22½ per cent. of tin. With less than 22½ per cent. of tin some of the originally formed $\alpha$ remained when solidification was complete, and the solid alloys consisted of $\alpha$ and $\beta$. In the alloy with 22½ per cent. of tin the $\alpha$ which had formed in the first stage of solidification had entirely disappeared at the moment of complete solidification, and the solid alloy was $\beta$ only. Between 22½ per cent. and 26 per cent. of tin the $\alpha$, which solidified at first, was all used up to produce $\beta$ before the alloy was completely solid, and any remaining liquid solidified as $\beta$

Ordinary bronzes usually contained less than 20 per cent. of tin, and thus, when solidified, consisted either of $\alpha$ entirely or of a mixture of $\alpha$ and $\beta$. The $\beta$ constituent, however, was not stable below about 500 deg. C., and at this temperature broke up into a mixture of $\alpha$ and $\delta$. Therefore, unless quickly cooled, the $\alpha$ and $\beta$ alloys when cold consisted of $\alpha$ and $\delta$. During cooling from 780 deg. C. the $\alpha$ absorbed some $\beta$, since the solubility of tin in copper increased as the temperature fell, but any residual $\beta$ decomposed at 500 deg. C., and was represented in the cold alloy by the $\alpha$ and $\delta$ "complex." The $\alpha$ constituent of the bronzes resembled the $\alpha$ constituent of the brasses both in mechanical properties and in appearance under the microscope. Also the $\beta$ material of the copper-tin alloys (although differing in colour) was like the $\beta$ of the copper-zinc alloys, and was distinctly malleable. The $\delta$ of the copper-tin alloys was hard, bluish-white, and very brittle, and corresponded to the $\gamma$ of the copper-tin alloys.

In both series of alloys the $\beta$ materials were in many respects similar, but in the copper-zinc it was believed until recently that the $\beta$, within certain limits of concentration, was stable at all temperatures, as indicated in Shepherd's diagram. In Roberts Austen's original curve, as in the 4th Report of the Alloys Research Committee, a small heat evolution at about 450 deg. C. was observed in the case of alloys between 45.8 per cent. of copper and 75.4 per cent. of copper, and a eutectic line was given on the freezing point diagram at about 450 deg. C., and between the above limits of concentration. Later, both Shepherd and Tafel observed no heat evolution at 450 deg. C., and failed to find any microscopic evidence of change in constitution at this temperature, or a eutectic. The possibility of an inversion at 450 deg. C. was therefore rejected, and the $\beta$ was considered as a stable phase at the ordinary temperature. Recently, however, Carpenter and Edwards had confirmed the original observation of Roberts Austen. They also gave an explanation of the change, and in a Paper before the Institute of Metals, in January, Professor Carpenter showed that on long annealing at a suitable temperature he was able to obtain copper-zinc alloys consisting of large crystals of $\alpha$ and $\beta$, although these alloys were originally composed almost entirely of what was apparently $\beta$. The explanation of the apparent stability of the $\beta$ was that at 460 deg. C. it was resolved into a very uniform and intimate mixture of $\alpha$ and $\gamma$ existing probably in a condition resembling a colloid solution. The $\beta$ thus appeared to have undergone no change. Diffusion and crystalline growth in brass at 460 deg. C. was very slow, and even when crystalline nuclei of $\alpha$ and $\gamma$ were present, Carpenter found that some ten days' annealing was required before any pronounced separation of $\alpha$ and $\gamma$ was observed, while seven or eight weeks' annealing was necessary in order to obtain a mixture of $\alpha$ and $\gamma$ in a coarsely crystalline condition.

This critical point in the brasses was probably of great practical importance, and in this connection it was of interest to recall the fact that Roberts Austen fifteen years ago attributed the improved mechanical properties of such special brasses as "sterro" and "Aich's" metal to the suppression of this point by the iron they contained. Roberts Austen compared the cooling curves of a sample of ordinary brass containing 61.2 per cent. of copper and a sample of Aich's metal containing 59.8 per cent. of copper with 1.5 per cent. of iron. In the former, the critical point at 460 deg. C. was distinctly marked, and in the latter it was absent.

A comparison of the equilibrium diagram of the copper-zinc series as modified by Carpenter and Edwards with the equilibrium diagram of the copper-

tin series showed that there was a direct resemblance between the general constitution of the alloys at the copper end of both series, the $\beta$ in both cases being resolved at a comparatively low temperature into a mixture of soft ductile $\alpha$ and hard, brittle $\gamma$ or $\delta$. It might also be recalled that there was a similar inversion of $\beta \longrightarrow \gamma + \delta$ at 566 deg. C. in the copper-aluminium series. In comparing the brasses and bronzes it must, however, be remembered that in the case of the bronzes the $\beta$ readily broke up into a mixture of $\alpha$ and $\delta$, both of which could be easily recognised as such under the microscope, while the similar structural separation of $\alpha$ and $\gamma$ from the $\beta$ of the brasses took place with difficulty and extreme slowness.

This difference was of very great practical importance, and furnished another instance of the industrial value of metastable equilibrium. If true equilibrium were as easily obtained in copper-zinc alloys as in copper-tin alloys, it would be impossible to produce the strong, malleable and ductile $\alpha$ $\beta$ brasses. Under ordinary conditions true equilibrium was never reached, and to this fact alloys, such as Muntz's metal and others containing the $\beta$ constituent, owed their useful mechanical properties.

### Discussion.

The PRESIDENT remarked that in practice the most important thing was the tensile elongation of metal, and he thought it would be a very useful addition to their present literature on the subject if attention were given to the physical properties of brass and bronze. When it was considered that practically the whole of the best bronzes in use contained more than about 10 per cent. of tin, and that common bronzes were made with additions of zinc, but the percentage of copper was rarely below 85 per cent., the margin of all these various mixtures on which they worked was very limited. What they aimed to get at was, what gave the very best results with the different mixtures. At the present time, with tin at an exorbitant price, they wanted to know with what percentage they could get the best results. Therefore, he thought exhaustive experiments with the various mixtures would bring out very interesting matter. Of course, with regard to lead, that was only added to assist the machining; any addition over 2 per cent. had a detrimental effect on these alloys. He would like to ask Mr. Hudson what, after repeated melting, became of the lead put into these alloys.

MR. H. COE said that one of the points which interested him was that Mr. Hudson had shown that in Muntz's metal the outlines of the original $\beta$ crystals could be traced by lines of $\alpha$ which separated them. It seemed to him that the $\alpha$ separated freely towards the exterior of the crystals at temperatures during the process of cooling, but that as the temperature fell the mobility became less, and $\alpha$ was deposited in the easiest possible place, namely, on the mass of the $\beta$ crystals. Another interesting point with regard to the copper-zinc series of alloys was the question of compounds; according to Baker a compound Cu $Zn_2$ existed containing 65 per cent. zinc and 33 per cent. copper. He obtained evidence of this compound by studying the behaviour of different alloys towards acids. According to the diagram shown by Mr. Hudson, there was no evidence of a compound at about 33 per cent. of copper, although he (Mr. Coe) thought it was pretty generally recognised that an alloy containing 40 per cent. of copper and 60 per cent. of zinc was a compound. A few of the micrographs with regard to the splitting up of $\beta$ into $\alpha$ and $\gamma$ were really Mr. Hudson's own, and they interested him (the speaker) more than did those of Professor Carpenter, because they showed certain facts more clearly.

A MEMBER asked whether there was any permeation of gases between the crystals.

MR. HUDSON, in his reply, referred to the Chairman's remarks, and said that he had for want of time passed over one or two slides which showed the influence of excess of impurity. Exhibiting these, he showed that lead, whether in the brass or in the bronzes, remained as lead. It was not taken up in the solid solution, nor did it form any compound, but was retained in the form of globules as lead. Tin, in the case of a copper-zinc alloy, could be held in solution in either the $\alpha$ or the $\beta$ to a certain small extent, so that in alloys which were made with a small percentage of tin, naval brass for instance, these quantities of tin were held in solution. Any excess of tin gave rise to the separation of what was no doubt the $\delta$ constituent of the copper-tin alloys. He then showed a micrograph of a copper-zinc alloy, containing an excess of lead, nearly 2 per cent. This showed the globular particles of lead distributed in the $\alpha$. He pointed out the tendency of the lead to occur between the crystals. No doubt that accounted for some of the want of ductility caused by an excess of lead, and also the advantage the lead gave with regard to turning properties, the crystals being somewhat broken up by these particles of lead. With regard to the effect of quenching 60-40 brass, one was to reduce the ductility of the alloy. The elongation was much reduced when the quenching from, say, 750 deg. C. was sufficiently rapid to prevent, or partially prevent, the separation of the $\alpha$ from the $\beta$. The tensile strength was high in the quenched 60-40 alloys, but these alloys when quenched were much less ductile than the original. With regard to compounds, he had purposely avoided mentioning the compounds between copper and zinc in order not to complicate matters, but the alloy corresponding in composition to $Cu_2$ Zn, (40 per cent. of copper and 60 per cent. zinc) was possibly a compound, and that compound was dissolved in solid solution in the $\beta$ and $\gamma$ phases. As to the effect of gases on the critical point at 460 deg. C., as far as he was aware the effect of gases was probably negligible. At this point the temperature was very low, and the diffusion of gases at that temperature, he thought, must be slight.

MR. G. HAILSTONE, in proposing a vote of thanks to the lecturer, remarked that Mr. Hudson was not dealing in his lecture with the alloy as a commercial article; he told them what occurred if they had pure materials, and the manufacturer, the practical man, must find out from his own experiments on the lines stated by Mr. Hudson what effect the impurity would have on the metal he dealt with. Mr. Hudson had used the terms $\alpha$ (Alpha), $\beta$ (Beta), $\gamma$ (Gamma), and $\delta$ (Delta) in naming the constituents of the various compounds that occurred in copper-tin and copper-zinc alloys, and possibly some of the members were confused by the use of these terms. They had got into the habit of knowing what was meant by "ferrite," "cementite," "pearlite," and so on in the iron-carbon series, but when it came to naming constituents with the letters of the Greek alphabet they might not so readily grasp the significance of this classification. Some of them possibly might think that the compounds Alpha, Beta, Gamma and Delta were the same compounds in the copper-zinc as in the copper-tin alloys.

MR. H. PEMBERTON seconded the vote of thanks, which was heartily adopted.

MR. HUDSON, in responding, thanked Mr. Hailstone for drawing attention to the point about the Greek letters assigned to the different constituents. They were simply names by which they distinguished them, and were used merely for the sake of convenience.

# Making Ingot Moulds in Dry Sand.

[ALL RIGHTS RESERVED.]

By Sidney G. Smith.

By the method about to be described, ingot moulds for ingots weighing up to 20 tons each, can be economically and expeditiously made. The writer took part in the development of the process, and will describe it in detail.

The preliminary requirements are as follows:—A rectangular casting-pit about four to five feet deep, with provision for ramming cores and moulds at either end, over which two overhead cranes travel. The pit should be about 50 ft. long, by 10 ft. wide, which would provide room for 20 medium-size ingot-

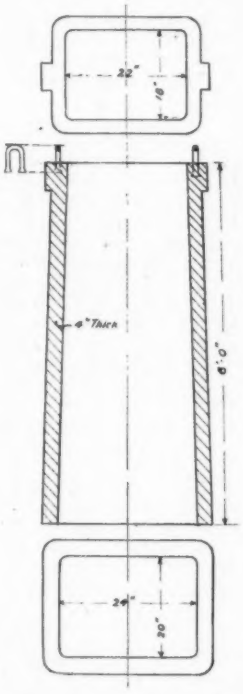


FIG. 1.—SECTION OF PLAIN INGOT MOULD.

mould boxes. A casting-pit of the dimensions given should be capable of an output of from 50 to 100 tons per day. It is a great mistake to stint pit area for heavy boxes, and is often the cause of accidents by trapping hands and feet. Further reference will be made later to the casting-pit arrangement.

Fig. 1 is a sketch of a plain ingot mould.

Fig. 2 shows a section of the table and mould for a plain, ordinary ingot mould assembled. The boxes, Figs. 3 and 4, are cast in open sand, and bolted together. When stripping the boxes after casting, the bolts of the cross-corners are loosened, which permits the box to lift off easily, leaving the sand adhering to the casting. When the box is lowered upon the ramming plate, the bolts are again made fast. With some designs of ingot moulds, it will be found necessary to part the box entirely to strip the casting.

Fig. 5 shows in plan and section the core bar. The core bar is faced across the bottom, this giving the core a true bottom surface so that it can either be hung upon a stove carriage or stand upon its own base when being stoved for drying, without being damaged.

Fig. 6 shows in section and plan the bottom plate which forms the bottom of the ingot mould. It is recessed for a thickness of about 1½ inches of loam. A print to correspond with the core required, with guide-pin template attached, is laid on the plate as shown, underneath the print being faced. The core is perfectly level, the fillets of the bottom plate and ring being faced and provided with guide pins and holes. This arrangement gives simplicity and trueness without the possibility of errors. Fig. 7

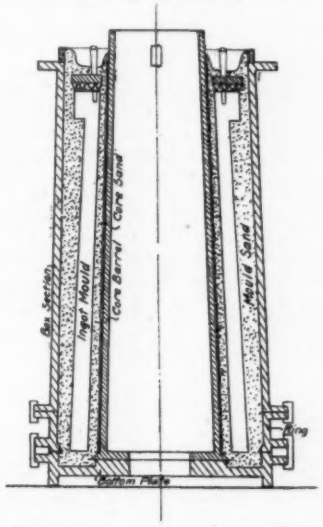


FIG. 2.—INGOT MOULD AND TACKLE.

shows section and plan of the ring. It is convenient to have this short length, although not absolutely necessary.

Figs. 8 and 9 show the cake dish and grid. The cake which passes over the top of the core has the runners and rises in, and closes the mould. In the plan view of the dish it will be noticed that holes are shown; these are for the runner gates, risers, and staples which are hung in the cake. Plenty of taper should be allowed in the dish so that the cakes will leave with ease when dried.

When preparing to ram the mould, the pattern and box are put on the ramming plate, Fig. 10, which is in the pit. The rammer plate, which should be faced right across, should be large enough for any pattern required, and should be fixed in one position and remain there. A centre hole and a hole at right- or left-angles should be drilled in the plate and dowells put on the bottom of all patterns to correspond with them; this arrangement fixes the pattern, and the boxes can be centred from it. It will be seen that bottom ramming boards for different sizes are dispensed with.

When the box is rammed the pattern is loosened, the box is lifted off, leaving the pattern down, and when there are projections these are dovetailed and drawn in, or otherwise formed with a core. The mould is then finished, blacked and dried. The

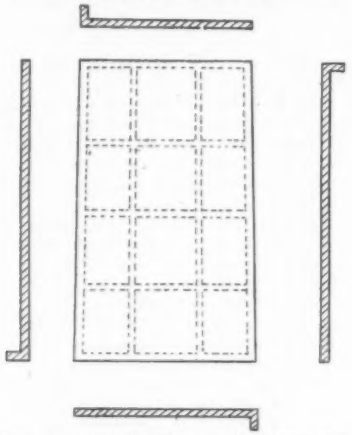

FIG. 3.—SIDE VIEW AND SECTIONS OF MOULDING BOX.

mould boxes are rather longer than the pattern so that the top of the runner cake will come about level with the top of the box, which will make it handy for cramping down. At least 2 inches of sand each side should be allowed for ramming.

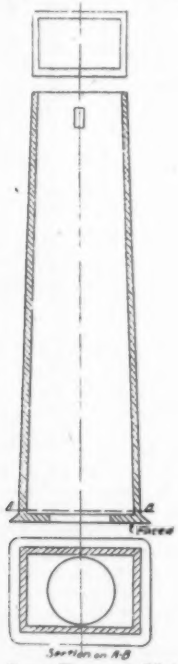


FIG. 5.—CORE BAR FOR MOULD CORE.

When preparing to ram the core, the bar is first lapped with bands of either hay, straw, or chip shaving. For ease this should be done with the bar hung in a swivel with ball bearings, or the revolving operation should be performed by some other mechanical device. After the bands have been smeared with soft loam, the core bar is lowered into the core box, which can be made either of wood or iron. An allowance of 2½ to 3 inches of sand on either side, including the band, should also be made for the core. When the core is rammed and liberated from the box it is carefully finished and washed with a good quality of blacking.

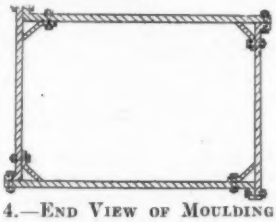

FIG. 4.—END VIEW OF MOULDING BOX.

The core is the all-important part of an ingot mould; the ramming must be uniform, for the absence of swellings or indentations in the core is imperative, as these would condemn the casting. The sand for the cores should be of medium strength, and milled for a short time only. For the mould the sand need not be milled, but should have some new

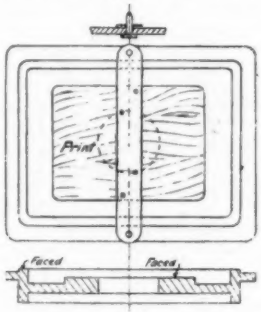


FIG. 6.—PLAN AND SECTION OF BOTTOM PLATE.

sand added daily to prevent it becoming weak, as a weak sand would produce rough and dirty castings.

Fig. 11 shows section of a tumbler ingot mould, which differs considerably from the plain ones. It will be noticed that the tumbler has a closed solid top, which necessitates the core being fastened from

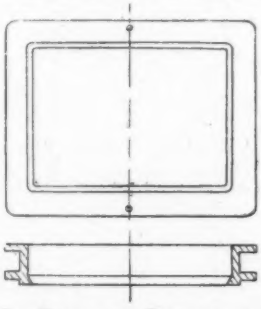

FIG. 7.—PLAN AND SECTION OF RING, OR BELL BOX.

the bottom with a large, stout cotter pin. The allowance of sand for ramming the mould is rather more than in the case of ordinary plain moulds, owing to the projections for tumbling.

Fig. 12 is another design which differs from the level tops, which necessitates an uneven cake dish.

The core is also tapered sharply at the top, to which the core bar must corespond, while also the side projections at the top are larger, for which reason it is more economical to make boxes that will follow the pattern; such boxes are made in halves and are covered castings. Although these boxes are more expensive to make, the advantages gained are the reduction of the large bulk of sand which would be required with straight boxes. It is important that the thickness of sand should be as uniform as possible for regular and economical internal drying with gas.

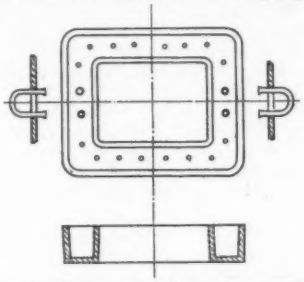

FIG. 8.—PLAN AND SECTION OF CAKE DISH.

Fig. 13 shows a drop weight for liberating the core bars. It is wise to liberate the core bar as soon as the casting is sufficiently solidified, which will depend upon its thickness. By so doing the core bar is released with less falls of the weight than if it is left until black cold. When the casting is set, the boxes and mould are lifted bodily, the bottom plate is prised off, and the box and casting packed up about 6 inches on four packings; the guide bars of the drop weight, which is hung up in a liberating catch, are allowed to enter the core bar, and the catch is then pulled, liberating the weight, which drops upon

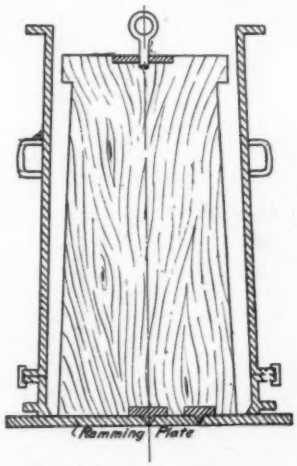


FIG. 10.—INGOT-MOULD PATTERN ON RAMMING PLATE.

the core bar. One drop of 2 or 3 ft. should liberate the bar to the depth of the packings under the box unless the mould has been allowed to stand too long, in which case several drops may be required to release it, owing to the contraction during cooling causing the metal to tighten around the core. The writer has made ingot mould cores without bands, but has had difficulty in releasing the core bar without involving occasional damage.

The illustration shows two guide bars, but these are only required when there is an internal strengthening rib in the core bar, which is necessary in wide, heavy ingot moulds, owing to the pressure. It will be noticed that the guides are loose, shouldered at the bottom face of the drop weight and cottered at the top; experience has shown that when cast in they very quickly crystallise during the work and break off. When making a drop weight it is wise to cast three square holes in it, one in the centre, as either one or two side guides can then be used, as required.

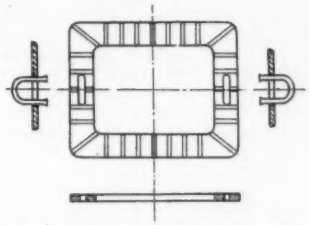

FIG. 9.—PLAN AND SECTION OF CORE IRON FOR CAKE DISH.

## Mixing, Melting, Temperature of Iron, Pouring, Feeding, etc.

All the above are important in making sound, durable ingot moulds, and require the close attention of those in charge of the work. Hematite iron is specified for ingot moulds, and this quality must be strictly adhered to; while also it should be kept within confined limits regarding the contents of silicon, phosphorus and sulphur, the last two of which should be low. Hematite irons, like other irons, are classified according to numbers or grades. Of the available hematite irons the writer favours, when no scrap is used, a No. 3 hematite, the approxi-

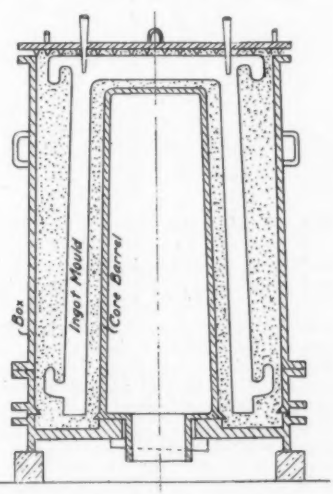


FIG. 11.—TUMBLER INGOT MOULD.

mate analysis of which should be, carbon 3.90 per cent., silicon 2.00 per cent., phosphorus 0.05 per cent., manganese, 1.00 per cent., sulphur, 0.03 per cent. Where much scrap is used, which should not exceed 25 per cent., a No. 2 iron is best, the approximate analysis of which is, carbon, 4.00 per cent, silicon, 2.25 per cent., phosphorus 0.05 per cent., manganese 0.90 per cent., sulphur, 0.04 per cent.

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The writer does not wish to discuss at the moment the question of analysis r. fracture; both must be considered in relation to other factors. A tough close iron is the most suitable for ingot moulds. The following analysis was given to the writer as of hematite iron from which ingot moulds endured 62 heats:—

Silicon, 0.063 per cent.; phosphorus, 0.059 per cent., manganese, 0.533 per cent.; sulphur, 0.063 per cent. The low percentage of silicon in the above is remarkable. As an ideal, and not impossible analysis for these castings, the writer would suggest:—Combined carbon, 0.40 per cent.. graphitic carbon, 3.30 per cent.; silicon, 1.50 per cent.; phosphorus, 0.05 per cent.; manganese, 0.75 per cent.; sulphur 0.02 per cent. The above is suggested by reason of the thickness and slow cooling of ingot moulds when made, and also the continual extremes in expansion and contraction when in use.

The iron should be well melted and come from the cupola at a high temperature. It is false economy, especially with hematite iron, to stint the quantity of coke, which should be good, hard and cellular, and contain less than 1.00 per cent. of sulphur. Not

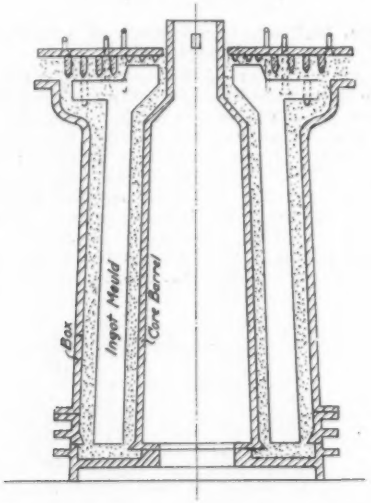


Fig. 12.—Small-necked Ingot Mould.

less than 2 cwts. of such coke per ton of iron should be allowed for melting. Although large ingot moulds range from 3 in. to 10 in. in thickness, it is a great mistake to have iron come from the cupola in a sluggish condition. The castings will be more enduring if the iron is melted very hot and allowed to cool down a little, than if melted sluggishly. It is not suggested that castings of such thickness should be poured at a dazzling whiteness; neither should they be poured when the iron is in a thick condition—evil will develop from both extremes. In the first there will be undue strains and sinkage; in the latter porous crustations in the casting, which would prove fatal to the ingot mould after the first heat. Steel at its high molten temperature would eat into such crustations; consequently there would be great difficulty in liberating the steel ingot from the iron mould. Of the two evils the first is decidedly preferable, but there should be no great difficulty in fixing upon the medium temperature which would avoid the above mentioned evils.

The castings should be poured fairly quickly. A casting that is poured slow, even with hot iron, will show a porous, crusty, uneven skin, and so far as its use for steel ingots is concerned it is only fit for the scrap heap. All ingot moulds should be fed with rods. The runner basin should hold a good quantity of iron to assist in feeding the casting where there is such thickness and weight; if feeding is neglected there will be found large spongy places and shrinkage holes where they are not required.

The plan of an ingot-mould foundry, shown in Fig. 14, is by way of suggestion, and its arrangement is considered from an economical and self-contained standpoint. A common drawback to most foundries is the bad arrangement of line approaches and the dependence for certain supplies such as boxes, loam, etc., upon somewhere which is not in close proximity. Regarding the plan, Fig. 14, it will be noticed that all the cupola's materials can be shunted with ease, and the slag and cinders removed daily. At the stove end of the shop are situated two small cranes. These are necessary for lapping the core bars with bands, and only need be made strong enough

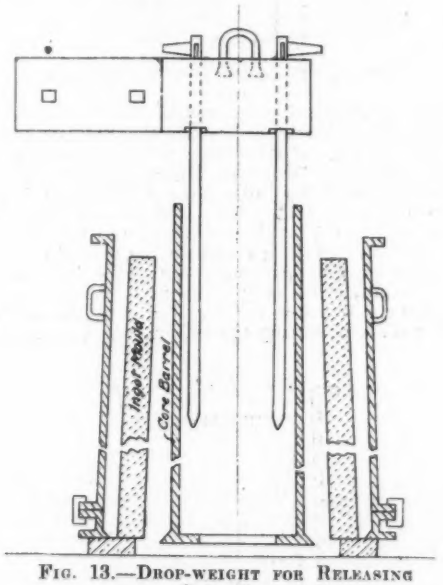


Fig. 13.—Drop-weight for Releasing Core Bar.

and of sufficient height for that purpose. As an alternative one crane in the centre would do, and in that case it would be well to arrange for its rake and height not to reach the ramming pit and core carriages, but to clear the travelling crane. Looking at the rectangular pit, it will be seen that in the middle provision is made for drying the moulds. At the main entrance end and the opposite end for ramming the moulds and cores, two fixed ramming plates at either end are arranged. The space between these ramming plates can be utilised for finishing and blacking without interfering with the ramming. The whole or middle of the pit area, as thought desirable, can be used for drying or casting, or one side may be used for drying and the other side for casting. If the latter plan be adopted, it would be wise to have the drying side 6 ins. higher at the bottom.

At the right and left of the pit two sand cellars are shown which may require some explanation. These cellars should be about the same depth as the pit, from 4 to 5 ft. by 4 ft. wide, and 8 ft. long; two pans with drop bottoms, rather less in depth than

the cellar and rather under 4 ft. square, should be put into the cellar, with lifting eyes for slinging; two movable steel joints should cross the cellar lengthwise, level with the floor, sufficiently strong to carry the ingot mould when cast, and the box. At a convenient time for stripping, the box with the casting is lifted on to the cellar and rested upon the joists. After the box is liberated and lifted off, the sand either falls or is knocked off into the pans in the cellar; the casting is removed and clay water is thrown upon the sand. The stripping is repeated in this way until the pans are full or the sand required again for ramming.

The advantage of the cellar and pan arrangement is the saving of time and labour while the sand is soaking, and also general cleanliness. When the pans are lifted out by the crane, the drop bottoms

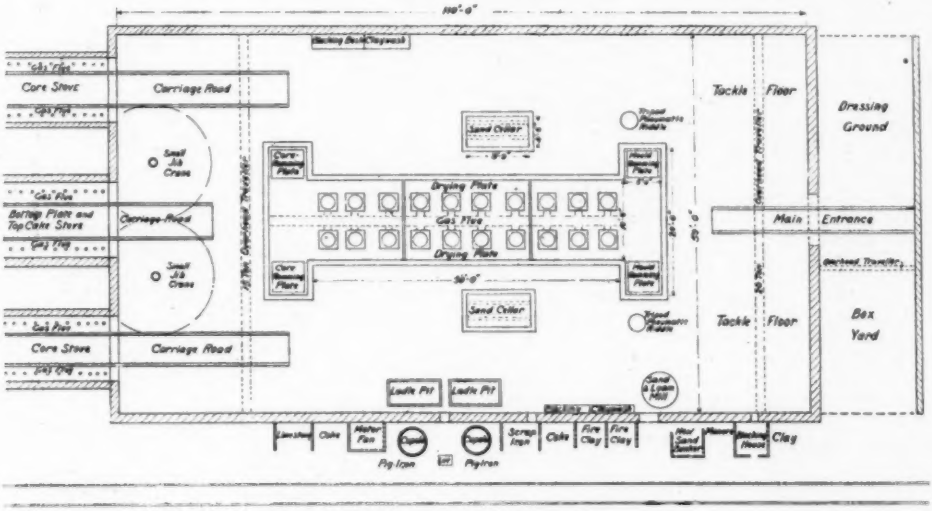


FIG. 14.—PLAN OF INGOT MOULD FOUNDRY.

are liberated and the sand falls near the tripod air riddle, and after a little new sand has been added, is passed through the riddle for further ramming. If the cellar arrangement were adopted, the sand mixer, as shown in the plan, should not be necessary. It should be stated, in reference to the sand-soaking cellar, that a larger bulk of sand will be required for constant use, because, during the time the sand is soaking, other sand will be in the boxes which are being cast, in addition to that which is being rammed during the same day; this will amount to about one-third more being in use, or soaking, than the amount used in the ordinary way of mixing daily—a small matter, which is more than compensated by the use of the cellar, both in time and labour of mixing.

With this method of making ingot moulds it is possible, but not advisable, except in very urgent cases, to mould, dry and cast ingot moulds the same day. A medium-size ingot mould and core could be dried with gas in from four to five hours.

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THE Lillebö iron mines, which are situated on the island of Stord, in the south-west of Norway, are to be worked on a rather large scale this spring. The transport difficulties are negligible, and 300 men will be engaged in the mining operations.

## Manufacture of Balls for Bearings.

In the manufacture of balls for bearings, the most general practice is to take a rod whose diameter is somewhat less than the finished ball; this is clipped off into cylinders, the cubical content of which is greater than the cubical content of the ball, to allow for finishing. This cylindrical piece is put between a couple of hemispherical dies and brought down to a roughly spherical shape. Since the edges of the die do not meet, there is a small circumferential fin, which is characteristic of such die work, around the centre of the ball. That is sheared off and then the ball forging is annealed, similarly to the material in the race, to remove the forging strains, after which it is rough ground. The grinding process is the whole essence of ball manufacture. If you have ever watched a youngster take a piece of putty in his hand and roll it, you know it grows round simply because he is constantly presenting a new axis of rotation. In grinding a ball, exactly the same principle is followed. The balls are placed in a circumferential groove of a large disc which lies in a horizontal plane. There is a grinding wheel below, and one above, which come down to bear on the ball, but the axes of those two wheels do not coincide. Therefore a constant spinning action of the ball is set up and a new axis is always being presented to the grinding action of the wheel; that same principle is carried on through successively finer grades of grinding wheels until the result is a round, smooth ball, which has not, however, a fine polish but a dull surface. The balls are all practically round but not exactly the same size. They are put in an ordinary tumbling barrel, which can be sealed, and they are tumbled in that with a grinding mixture. To a very slight extent it destroys their sphericity, but only to about 0.0001 of an inch. The balls are all round when they come from the machine, and highly polished, but they are of widely different sizes. For instance, in each lot the total range may be two or three thousandths of an inch, and the balls must therefore be sorted to exact size. One widely used scheme is to let the balls roll between plates at a very slight angle to each other. When a ball comes to the place where it falls through, it falls into a pocket or container below.—"Journal of the Western Society of Engineers."

# "F.T.J." Bookshelf.

### The Heat Treatment of Tool Steel.

*By Harry Brearley. London: Longmans, Green & Company, 39, Paternoster Row.*

The author here presents a book for the use of the trained artisan and foreman whose business it is to produce steel objects and tools for various purposes. The book is full of practical points on the characteristics, appearance and defects of tool steels, many of which are common knowledge amongst competent tool-steel workers, while also there is a strong sprinkling throughout of laboratory facts.. We may at the outset, however, state that the ground covered is so wide that the author would have done better had he confined his attention to the simple practical handling of tool steels under heat treatment, thus occupying considerably less space, or else have elaborated many of the fundamental facts from a scientific standpoint. As it is there is a suggestion of introducing a number of facts (both practical and scientific) to give a conventional completeness to the scheme, without giving full consideration to their importance in relation to the subject. In the light of modern conditions and requirements it is practically impossible to leave out the scientific side of the question, no matter how purely practical may be the reader; but once that side is taken up it is better to treat it thoroughly than in a casual manner. The author is in a position to deal fully with the question of tool steels in view of his long service with Messrs. Thos. Firth & Sons, Limited; and that he has a thorough grasp of the subject is evidenced by the many practical points that are brought out. Much useful information is embodied in the chapters on forging, annealing, hardening, tempering, and straightening, while sound commonsense and instruction, resulting from the author's own experience, characterises the chapter on defective tools. Various hardening plants are described and illustrated, and in a chapter on pyrometers the values of different instruments are discussed. The latter chapter embodies many hints on the use and calibration of pyrometers, and should be very useful to the practical man. The portion dealing with case-hardening presumes a general knowledge of the process, and discusses a number of points in connection with the work. Alloy steels are dealt with in a dozen pages, the matter given being a general summary of available information. Several important points, however, are stressed, as, for example, the fallacy of believing that high-speed steel cannot be spoiled by burning or over-heating; but there is very little really new in this chapter. In an appendix, short articles deal with "Cupped Wire," or failure due to hard centre, "Apparatus for making Thermal Curves," and "Grinding Sparks," the latter noting the characteristic differences in the sparks from different classes of steel. The book, on the whole, will be found very useful, and though some may be disappointed at the lack of special information, it will be appreciated by a wide circle of makers, merchants, and users of tool steels. As a text-book on the subject, however, it could well bear elaboration.

### Cast Iron in the Light of Recent Research.

*By W. H. Hatfield, B.Met., A.M.I.Mech.I. London: Charles Griffin & Company, Limited, Exeter Street, Strand, W.C.*

This is, without question, a volume which should be in the hands of every foundryman who is interested in the science of his calling, or who realises that commercial success in foundry work is intimately connected with an appreciation of the scientific facts underlying the phenomena exhibited by iron in its various stages of manufacture. Mr. Hatfield's name is familiar to most readers of this journal, and there is much in the book before us which recalls his different researches and papers presented before technical associations. It will, of course, be understood that he writes with that intimate knowledge which comes of combined laboratory and works investigation, and the compilation covering his own and others' researches will be accordingly appreciated. Since the equilibrium diagram of the iron-carbide system throws so much light on the problem presented by the metallurgy of cast iron, the author starts by describing this diagram and the nature and constitution of the alloys in question. The succeeding chapters deal with the influence of other constituents, such as silicon, phosphorus, sulphur, manganese, and the rarer elements; and the remainder of the volume is devoted to the consideration of the influences incidental to the modes of manufacture, such as casting temperatures, shrinkage and contraction, and heat treatment generally. The work of most of the important authorities at home and abroad has been reviewed and summarised, but the author's own experience is largely represented. Professor Turner's researches, for example, figure considerably in the chapter on the influence of silicon, while the work of Dr. Stead and Professor Arnold in connection with phosphorus, is drawn on. The same applies to other chapters, a very fair summary of such work being given. The portion dealing with the growth of cast iron after repeated heatings is in essence the account of Dr. Carpenter's work on that subject. An important chapter summarises the effect of heat treatment on cast iron, and draws on the work of a number of authorities; while similarly the treatment of the mechanical properties of cast and malleable cast irons is concise and clear. Much valuable information is also contained in the chapter on furnaces and slags, in which Swinden's recent researches are embodied, amongst others. Finally, two useful appendices present respectively a metallurgical nomenclature and a last of typical pig-irons on the market. Though not unduly voluminous, the book presents in clear and concise form a mass of information which, while available in various publications and societies "proceedings," is not readily accessible to the practical man, and is also often embedded in a confusing accompaniment of scientific detail. To those whose opportunities for study and research work are restricted, and the average foundryman certainly comes under this category, the book should strongly appeal. The author is to be thanked, not only for his own research work, which is presented, but also for the way in which the work of older and contemporary workers in the scientific field has been dealt with.

FREDK. BRABY & COMPANY, LIMITED, ECLIPSE WORKS, GLASGOW.—We have received from this firm a copy of their new high-class catalogue just issued, dealing with metal casements, sashes, etc. The book is of considerable interest and use to constructural contractors and others using this class of casement, for it illustrates the great adaptability of the material and the wide range of application covered. The sizes of sections made by this firm are respectively 1½ in., 1¼ in., and 1 in., and the joints and corners are welded. Hopper ventilators form another speciality of the firm's which is illustrated in the catalogue.

# Electric Furnaces.

At a meeting of the Manchester Association of Engineers held recently, Mr. Cecil Myers read a Paper, in the course of which, after touching upon the principles of the electric furnace, distinguishing between the arc and induction types, he proceeded to give brief descriptions with illustrations of the construction of the different types of furnaces now in operation, including the Héroult, Stassano, Girod, Kjellin, Röchling-Rodenhauser, and Frick.

### Furnaces in Sheffield.

Before the beginning of 1911, the Héroult furnace at Edgar Allen & Company's, in Sheffield, was the only arc furnace in steady operation. In January three Héroult furnaces were commenced in England, at Messrs. Vickers and Thomas Firth & Sons, Sheffield, and at Lake & Elliott's, Braintree, Essex. A Kjellin furnace, for demonstration and manufacturing purposes also, started at about the same time in Sheffield, and the output of England for 1911 should amount to about 13,000 tons. A 15-ton Héroult furnace was working, or just about to do so, at Skinningrove, and was expected to turn out 200 tons per day. Kjellin induction furnaces also had been working during this period satisfactorily at Messrs. Vickers and at Messrs. Jessop's, in Sheffield, and an experimental furnace at the University of Sheffield. Great progress was expected to be made in Germany with electric furnaces during this year, when Héroult furnaces of 25 and 22 tons' capacity per charge were to be constructed. In September, 1911, the largest size was two 15-ton Héroult furnaces at South Chicago and Worcester, belonging to the United States Steel Corporation, who had recently acquired the Héroult patents for America and would probably erect several more furnaces shortly.

### Chemical Action.

It might be interesting here to look into the chemical actions that take place during the refining, the dephosphorising, and the desulphurising of the steel in the bath. The action takes place in two stages. In the first, which is the oxidation period, the carbon, silicon, manganese and phosphorus are oxidised, and in the second, which is the de-oxidation period, the metal is dead melted and the sulphur eliminated. The first action is arrived at by adding to the charge certain quantities of lime and oxide of iron, which under the influence of the high temperature oxidise the carbon, silicon and manganese and remove the phosphorus as calcium phosphate. The slag after this operation is removed from the bath and further quantities of lime (and sometimes carbon) are added; this is the second stage, when the sulphur passes into the slag as calcium sulphide, which is not soluble in the metal bath. In the open-hearth furnace this calcium sulphide would very readily be oxidised into calcium sulphate, which would combine with the iron to form sulphide of iron and so go back into the steel. In the reducing atmosphere of the electric furnace this cannot take place, so that it is possible to remove the sulphur to almost any extent.

### Data from Actual Practice.

This Paper would hardly be complete, continued the author, without a little actual data with reference to charges, additions, power used, etc. Table I. is a copy of a report on seven consecutive charges from an 8-ton Röchling-Rodenhauser furnace, and Table II. is from a Héroult furnace.

Table II.—*Analyses of Steel and Slag taken at different Periods of Heat.*

| E 711. | | No. 1. When slag was melted. | No. 2. When slag was white. | No. 3. Just before tapping. | Finished steel. |
|---|---|---|---|---|---|
| | | Per cent. | Per cent. | Per cent. | Per cent. |
| Steel, Sulphur | | 0.053 | 0.037 | 0.019 | 0.014 |
| Slags at same periods | $SiO_2$ | 20.10 | 19.20 | 19.60 | — |
| | $Fe_2O_3$ | 1.30 | 0.90 | 1.00 | — |
| | $Al_2O_3$ | 4.00 | 5.20 | 6.20 | — |
| | Ca O | 60.00 | 64.20 | 61.30 | — |
| | Mg O | 5.04 | 3.96 | 4.36 | — |
| | S | 0.63 | 0.90 | 1.26 | — |

In concluding, the author remarked that there was very little doubt that for many purposes in steel-making, the electric furnace was the furnace of the future, especially in view of the great strides it had made during the past ten years. There was no doubt now in the minds of steel-makers who had had actual experience with up-to-date furnaces, that it was possible to make steel equal to the best ever produced in Sheffield at less cost than could be done in the crucible.

Table I.

| Number of charge. | Time. Charge | Time. Tapping. | Weight of steel charged in kilos. | Ferro-silicon, kilos. | Ferro-manganese, kilos. | Mill scale, kilos. | Spiegel, kilos. | Tapping weight, kilos. | Total power kw.-hours. | Total power per 1,000 kilos. | Analysis of charge, basic steel. P. | Analysis of charge, basic steel. S. | Analysis of finished steel. C.C. | Mn. | Si. | P. | S. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | p.c. | p.c. | p.c. | p.c. | p.c. | p.c. | p.c. |
| 2,668 | 4.55 | 8.36 | 5,673 | 35 | 2 | 90 | — | 5,500 | 1,681 | 291 | 0.059 | 0.065 | 1.04 | 0.33 | 0.18 | 0.012 | 0.024 |
| 2,669 | 9.00 | 12.20 | 5,472 | 35 | 3 | 90 | — | 5,600 | 1,688 | 301 | 0.050 | 0.067 | 0.79 | 0.33 | 0.26 | 0.012 | 0.029 |
| 2,670 | 12.35 | 3.50 | 5,385 | 25 | — | 90 | 100 | 5,600 | 1,781 | 318 | 0.060 | 0.069 | 0.16 | 0.33 | 0.015 | trace | 0.032 |
| 2,671 | 4.25 | 7.20 | 5,430 | 35 | 45 | 90 | — | 5,600 | 1,425 | 255 | 0.054 | 0.067 | 0.64 | 0.89 | 0.16 | 0.020 | 0.016 |
| 2,672 | 7.45 | 10.45 | 5,485 | 25 | — | 90 | — | 5,600 | 1,288 | 230 | 0.072 | 0.079 | 0.96 | 0.33 | 0.084 | trace | 0.014 |
| 2,673 | 11.25 | 2.20 | 5,480 | 30 | — | 90 | — | 5,600 | 1,321 | 236 | 0.048 | 0.059 | 1.20 | 0.33 | 0.12 | 0.015 | 0.020 |
| 2,674 | 2.55 | 5.40 | 6,030 | 35 | 45 | 90 | — | 6,200 | 1,371 | 211 | 0.067 | 0.067 | 0.51 | 0.83 | 0.15 | 0.026 | 0.018 |

### Discussion.

Mr. Bedson said that from the commercial point of view his opinion was that electric steel was not going to be much better than ordinary steel made in the open-hearth furnace. Of course, a great deal depended upon the quality of the ore. They had to bear in mind that the open-hearth furnace had the experience of many years behind it, and, of course, the melters had become exceedingly expert. The analyses given by Mr. Myers were certainly very good, but he (Mr. Bedson) could give figures for open-hearth steel made from good ores which showed even greater purity than the metal from the Kjellin and Röchling-Rodenhauser furnaces.

Mr. Foster gave some information as to the cost of current. A customer of his had occasion to go very closely into the cost of electric power, his investigations extending over several months, and the figures obtained were as follows:—Taking capital charges, stores, labour, interest, depreciation—in fact, every charge except the cost of land, but including buildings and foundations—and taking coal at 8s. 6d. a ton, with ammonia-sulphate recovery, current could be produced for 1.5d. per unit. He might say that the ammonia recovery had an appreciable effect on the cost of the current. If they knocked out the cost of fuel, as they might do when they had blast-furnace or coke-oven gas, it fell to 1d. per unit, and on that basis the cost of refining steel was not very great. The figures given by Mr. Myers varied from 200 to 300 kw.-hours per ton of steel, and on the basis of 0.2d. per unit—which would cover the total cost of delivering the metal into the furnace—it would be only 5s. per ton for refining. That seemed an exceedingly low cost. To his knowledge some electric furnaces had been installed in this country for the purpose of making use of a cheap and otherwise not very valuable ore, and converting it into first-class steel. There was nothing special about electric steel—nothing mysterious—but the furnace was so completely under control that they could get, within reasonable limits, practically any result they desired. They were able to get a quantity of steel which was roughly of the same general nature as that obtained from the open-hearth furnace, but had been further refined, and therefore was of higher quality. It might be argued that the extra special refinement of electric steel might remove some small impurities (so-called) which were really of value in the steel. For instance, it was recognised that some of what were called impurities in the steel were really essential constituents. Carbon, silicon, and manganese might be termed impurities, but they were necessary. Of course, if they were present in the wrong proportion, or if the wrong ones were present, they became impurities in the true sense, and a defective result was obtained.

Mr. Ibbotson said he had had some years' experience of electric furnaces, and he found that the amount of current for refining was, under equal conditions, practically about the same in the arc and in the induction types. Comparing the same two types for power, which, of course, was an important matter, the power-factor in the case of the arc furnace might run up to 0.9, but for the induction furnace 0.6 was fairly high. Therefore, the comparison was favourable to the arc furnace, but on the matter of variation of current, while in the induction furnace it was a perfectly steady load and current, in the arc everybody found by experience that it was apt to fluctuate a little. Thus what was gained in power-factor might be lost in the variation of the current, and it meant that in the arc furnace they had a machine that would stand some overload, whereas in the induction furnace they had not, and they had to have a larger machine because of the low power-factor. There was the question of the starting up of the induction furnace. In doing so from cold the usual thing was to have a cast- or wrought-iron ring, which was used for drying the lining, and that was melted down and the charge put in. Of course, to keep the current on it was necessary to keep a portion of the charge in. The arc furnace had an advantage there in that it could start every time from a cold charge.

Mr. C. K. Everitt said he thought that in England the electric furnace could only be commercially used as a refining, and not as a melting, furnace. It was very uneconomical as far as melting was concerned. The fact that they got reducing slag on the top of the metal was a great help to the steel-maker, especially in making alloy steels. A question had been raised as to the loss of chormium and vanadium and other metals, but when they could introduce those metals into the bath with a reducing slag on the top, the loss was certainly extremely small—no more than it was in connection with crucible steel.

Mr. Adamson suggested that Mr. Meyers might be able to make some further reference to steel castings. Engineers who were users of steel castings hoped that when the electric furnace was more fully established in this country they would obtain more reliable steel castings than were obtained at present from the furnaces in use.

In replying, Mr. Meyers said that most certainly one could make steel as low in phosphorus in the open-hearth furnace as in the electric furnace, but it would take an enormous length of time if they were starting with the same raw material. The electric furnace could make the very highest quality of steel, as far as the purity went, even with the very lowest quality of raw materials. If they used in the open-hearth furnace high-quality raw materials, like Swedish iron, they could doubtless get a very good final product. But the electric furnace was generally used on charges—from a mixer or from a Bessemer converter, or from an open-hearth converter—which were high in sulphur and phosphorus. As far as he could see, the idea in making high-quality steels in most processes was to get something as near to the analysis of pure iron as they could. Mr. Adamson had asked whether they could obtain from electric furnaces steel castings that were quite good. He could, if he paid for them, but just now the cost of steel castings from electric furnaces would come to more money than Mr. Adamson would care to pay, and he doubted whether they would be very much better really than the castings he got from any of the good firms in Sheffield. Mr. Foster had spoken about electric furnaces taking out elements which were useful in the steel. Of course, the electric furnace would take out some of those. But, in nearly all steel processes, especially in crucible steel, they took out almost everything but iron, and added, after that, the carbon, silicon, manganese, or other metalloids.

## Women in the Foundry.

At a special meeting of the Newark Foundrymen's Association, N. J., U.S.A., held on March 1, a protest was made against the enactment into law of a measure known as Senate Bill No. 325, which has been introduced in the New Jersey Legislature and is now in committee. The Bill is intended to prevent the employment of women in foundries as core makers and moulders. Energetic opposition was determined upon, and it was voted that a delegation should appear in protest at a hearing before a committee of the State Senate. Mr. George DeLaval, of Henry R. Worthington, Harrison, N. J., conceded the right of the Legislature to make laws insuring proper sanitary and moral surroundings for women and girls, but disputed its right to say that they should not work at certain employments. He said investigation has proved that the women working in the Worthington works are employed under better conditions than in many garment shops and places where thousands of women are employed. The women core-makers and moulders are provided with proper accommodation of various kinds, including a suitable place to eat their luncheon, and the women who operate in the manufacture of meters are protected in every way against accident. Speaking of the ability of the women, he said that as compared with men and boys they did better work and more of it, and told of a contest between four women and four men moulders, where at every stage of a moulding operation the women proved superior to the men.

# Some Castings Troublesome to Run Up Sound.

By Walter J. May.

From time to time it happens that castings do not run up sharply and well, a matter which often puzzles those who have to deal with them. Beyond this there will occur fractures due to shrinkage, which should not apparently appear; and while possibly the casting will come all right with one metal or alloy, it will not, perhaps, run up with another. In the general result this is unsatisfactory in both the foundry and machine shop, but particularly will the foundry have to take the blame.

Some particular shapes will not run sound except under certain conditions, one example being shown in section in Fig. 1, and in top plan in Fig. 2. Either the recessed part of the boss will come dirty and not turn up clean, or the arms will be partly fractured owing to the core not giving enough with the shrinkage of the outer cylinder, and clearly in certain metals special care has to be taken. Even if the core is soft enough the recess in the boss is likely to be dirty, and for this reason the boss section should be as shown in Fig. 3. The core should be especially

Fig. 1.

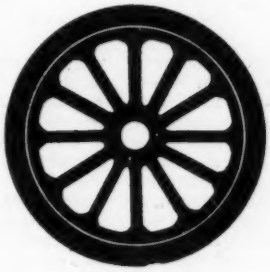


Fig. 2.

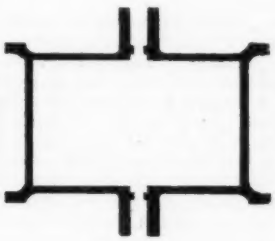


Fig. 3.

Now, taking the usual method of making a machine, the real origination is in the drawing office, and two points are usually aimed for—a nice looking drawing, and the saving of machine work, the question as to how castings can be best made not always being considered of much importance. Following on the work done in the drawing office comes the pattern shop, and here, again, the appearance of the patterns very often has too large amount of attention, unless the men have been attached to a trade foundry for some time. Of course, there is more practical knowledge and skill shown in the pattern shop than in the average drawing office, but still the peculiarities of various metals are not

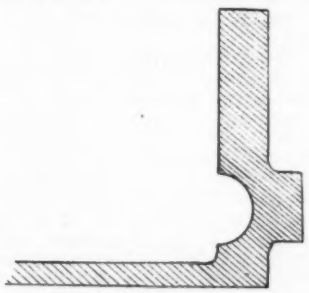


Fig. 4.

generally sufficiently well known, and hints from the foundry are too often resented; but, generally speaking, the average moulder is quite as much desirous of turning out presentable work as is any other person in the works, while also the moulder is more alive to the limitations of his art. A moulder does not like turning out ugly chunks of metal, and the majority of moulders would prefer to be on highly finished work, which give full scope to their abilities.

soft for the kind of metal used, and even then curved arms would be preferable as being more able to stand against contraction.

It is a curious fact that while some metals will conform to almost any outline, others will object to run round a curve, as shown in the section in Fig. 4, while running up cleanly in the section shown in Fig. 5. Aluminium often behaves in this way when the exact temperature for pouring is missed. Some bronzes, also, show an objection to running up sharply on acute angles, especially when cast in green-sand moulds, although rounded edges run freely enough. Where the work has to be machined this difficulty can be overcome by having the edges of a rounded

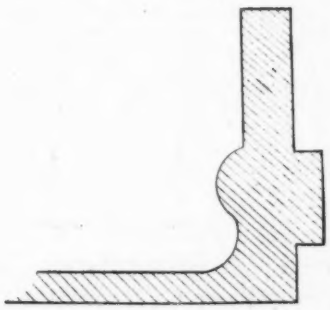


Fig. 5.

outline, of course, giving additional metal to be removed; but in cases where the casting has to be left untouched it will be necessary to use dry moulds, even though this may involve additional foundry costs, and often it may be necessary to use some fluxing medium, such as dry chloride of zinc, to cause the metal to flow freely.

The pouring temperatures of metals and alloys

have to be carefully considered where difficult castings have to be made, for there is a point where the maximum fluidity occurs, and often it will be found that with increase of temperature above this point the fluidity is reduced. The addition of a small percentage of such a metal as aluminium will in some cases increase fluidity, but care has to be taken that it does not act injuriously in other ways. In some cases the use of some deoxidant flux may be useful by clearing off or bringing to the surface occluded oxide and other "dirt," but some care must be taken in its selection .

Metal which has been very much overheated or "burnt" cannot readily be brought back to make sound and clean castings, and, as a general thing, such metal should be reserved for common, rough work, where neither appearance nor strength is of importance. Indeed, it is never a good plan to include "burnt" metal of any kind in melting for good work, as sooner or later its effects will show up.

When pouring troublseoe mcastings it becomes very necessary that metal be extremely well skimmed, because all sullage rises on the surface, and when this reaches a difficult point in the mould, as shown in Fig. 4, it gets entrapped and shows up conspicuously, more particularly when the skin is machined off the casting. In addition, there is either a porous spot or a hole formed. Besides this there is also the danger of choking the free flow of metal, more or less, and thus preventing some part from running up, while, in any case, a waster will be made. With simpler and more straight-lined work probably the sullage would be carried to the top of the casting, and where provision is made for the purpose of collection or removal no harm of any moment would occur; but this is never the case with intricate work of any kind, and particularly where grooves or projections occur on the vertical parts of a casting while being poured.

In thinning out the backs of castings it must be borne in mind that metal does not readily work up for sharp angles, and it is better to have a series of curves at the back (and usually the uppermost side) of a casting with even a good running metal or alloy, while with such stuff as aluminium this is particularly necessary, or there will be holes in abundance. In every case molten metal when cooling assumes a curved form of crystallisation, and if a square bar of some open-grained iron or similar metal be broken across squarely this will be readily seen, and on this the faults of very many castings will be found to depend, the removal of sharp angles making all the difference in the running up of the metal.

Often the position in which a mould is poured will cause the required difference in the running of the metal, as also will the position and size of the runner and ingate; but these are matters of detail which the moulder has to work out for himself quite apart from any question of patterns or metals.

## German Investigations on the Strength of Cast Iron Columns.

As the consequence of a decree of the German Government limiting the allowable load on cast-iron columns for buildings to 6,600 lbs. per sq. in., whereas it was formerly 9,250—and this change without being based upon a definite knowledge on the subject—the German Foundrymen's Association has appointed a commission of experts to look into the matter closely, and report its conclusions.

The establishments interested in the production of cast-iron columns in commercial quantities were interested, and a fund of £5,000 is now being collected to defray the necessary expenses of the elaborate investigation. In order to get a definite and satisfactory Governmental settlement of the question, the tests proper are carried out at the great Government Testing Bureau of Gros-Lichterfelde, near Berlin, and by Government officials. Offers will be called for from foundries making cast-iron columns regularly, to furnish the test pieces wanted, payment to be made from the fund raised. This makes it an object for the foundry securing the work to turn out the proper article—also for the Committee to demand it. The results will be published, but the identity of the firms doing the work kept confidential.

As it has been customary to make compression tests on small cylinders $\frac{3}{4}$ in. to $1\frac{1}{2}$ in. diameter, and of similar height, the same tests will be carried out in this work, so that the results obtained may be comparable with previous experience. Coupled with these, however, will be elaborate tests on regular columns of the dimensions given below, so that knowledge gained by testing small blocks may be coupled with full-sized specimen investigations. The columns in question are to be cast at the same time that regular orders are executed in the shops, and of the regular column mixture.

The following sizes are contemplated :—Diameter of column, 4 in., 6 in., 8 in., 10 in., and 12 in. Thickness of section for the respective diameters, 0.4 in., 0.6 in., 0.8 in., 1.0 in., and 1.2 in. The length of the columns to be, 4 in., 8 in., 12 in., 16 in., and 20 in., for the 4-in. diameter and 0.4-in. thick set. Similarly 6 in. to 30 in. length for the next set, 8 in. to 40 in. for the next, 10 in. to 50 in., and 12 in. to 60 in. for the last two sets. This means a series of twenty-five columns to be made from each cast. While these columns are cast, the same metal is to be poured into cylinders 0.4 in., 0.6 in., 0.8 in., 1.0 in., 1.2 in. diameter and the same dimensions respectively high.

Furthermore, as columns of the type above described should be tested not only under compression, but also for bending, so that actual conditions of service are approached, the following columns are to be cast from the same iron, and are to be tested transversely. Diameter of columns, 4 in., 6 in., 8 in., 10 in., and 12 in. Corresponding thickness of section, 0.4 in., 0.6 in., 0.8 in., 1.0 in., and 1.2 in., and length of each of the above five columns to be 11.12 ft. (4 metres). All the above-mentioned hollow columns are to be cast flat, and the test cylinders vertical.

All castings intended for the compression tests are to have their ends turned off and parallel to each other, the metal removed being at least half the thickness of section. The chips from the finishing cut of about 0.04 in. are to be saved for analysis. Five sets of analyses are to be made, one each from the set of columns 4 in., 6 in., 8 in., 10 in., and 12 in. diameter. The five columns of each diameter with corresponding metal thickness, compression cylinders and long transverse test columns, are presumably cast from the same big ladle. The cost of making such a test is estimated at £65, and to get a good average of the work of a foundry three sets of tests, each cast on separate days, should be provided for—making a total cost of about £200.

To get the average condition of the whole cast-iron column industry, six foundries would have to be selected, one each from the following districts :—Westphalia, Hannover, Silesia, Hamburg, the Palatinate, and Munich. There are about 125 foundries in Germany making a sufficient tonnage of cast-iron columns to warrant them becoming interested in the movement. A first subscription of £100 from one firm heads the list, and the German Foundrymen's Association has guaranteed a further £250, if required.

# Indian Iron and Steel.

Speaking recently before the Staffordshire Iron and Steel Institute, Mr. Isaac E. Lester (general manager of Messrs. C. Akrill & Company, Limited, ironfounders, West Bromwich) discussed the subject of "Indian Irons," of which he made a special study during five years' work in India.

Tracing the development of smelting in India, Mr. Lester said that the "Lohari," or iron smelter, was so by birth, according to caste. He was no metallurgist, but did just as his fathers had done before him. He cleared a patch of jungle, built his house of clay or mud, dug his wells, and employed the clay or mud therefrom, or any other mud, to build his furnace. He used no kilns, but burned his charcoal in a ground hollow, piling on wood until he had sufficient in hand; he then covered with breeze and debris from a previous operation. He preferred a sol or other fairly hard wood, or failing these, bamboo. The actual burning was done by the old men and womenfolk, aided by the children. The ore used was that requiring least trouble in getting, generally picked from off the surface. Often slag heaps of ancient workings were exploited with equal success. The Hindu smelter was not learned in quantitative results, and so long as the ore yielded iron he was satisfied. The furnace was roughly cylindrical in shape, 3½ ft. high and 2 ft. in diameter outside, tapering from 9 in. diameter inside at the top to about 11 in. at the bottom. The top was roughly funnel shape, so made as to hold a couple of baskets full of ore and charcoal, with which the furnace was filled. The furnace was hand-made throughout, and dried first in the shade and then in the sun for a whole day. A square hole of about 10 in. was left in the front of the furnace, which was built up when the tuyeres had been inserted and the furnace was ready for a charge. Blast was vigorously applied until the whole was well alight. On this about a seer (2 lbs.) of ore was put in and three seers of charcoal, and the like addition was repeated until the furnace was charged full to the top. As the charge sank, fresh additions were made until the full charge of 20 seers, or 40 lbs. of ore, was exhausted.

From time to time, a little hole was made near the tuyere, from which the slag was allowed to escape after the whole charge had sunk beneath the funnel; the bellows were kept at work for a quarter of an hour, and then the tuyere and adhering front were removed. The unconsumed charcoal and the bloom or sponge and adhering slag were taken out, the iron sponge was isolated, water was sprinkled on the glowing charcoal, and the product was then, while hot, transferred to a rough iron anvil, on which it was beaten into the desired shape according to ultimate use. The shape usually preferred was a rough rectangular piece, which was sometimes cut through there and then into three or four pieces; these were afterwards heated and forged separately, the worker using the same bellows or hand blowing with matt punka on a low charcoal hearth; or the metal was sold at the bazaar for the use of the smith. The bellows were very interesting, and were exactly of the same kind as used by the Loharis at Doocha in Bengal.

Experiments made at Jauli, in the Central Provinces, during a winter camp, proved the existence of an ore which should be as famous in India as the Mesabi was in the United States. This might be called an unctuous fine red iron ore; the natives called it "lal lona mutti," or red iron clay—clay which, with a simple method of river washing and the usual additions, was used as paint for ironwork. There was a vast hill of this ore, rising some 200 feet, and running for nearly three miles, from ½ to 1 mile through the hill, above the ground level. How much below had not been determined. Its analysis where the ochreous deposit was concentrated showed all ferric oxide with but 1 to 2 per cent. siliceous matter. An average estimate of the whole gave 75 per cent. $Fe_2O_3$.

Observed charges worked in the furnaces at Jauli and Jubulpore gave results in a thrice-worked bar made from a sponge (which consisted of a whole charge weighing 85 lbs.) on a checked analysis as follows:—C. 0.477, Mn. nil, Si. 0.082, S. nil, P. 0.038, Fe. 99.4 The drillings were taken from a 1 in. bar, pounded in a mortar; the whole then sieved and washed in alcohol, thus ensuring removal of all charcoal. The important effect of the extra working was very marked in the proportion of carbon, seeing that a previous analysis had revealed as much as 0.7 per cent. C. in the once-hammered bar. The speaker found the process in vogue hereabout similar to that worked on a large scale at Doocha in Bengal, previously mentioned, but with the difference that bellows in the Central Provinces were of a large accordion type, and the results rather less economical.

In all cases of well-worked bars, the process was one which might be said to make its own selection in the above sense. The low carbon content was always variable, and with even 0.4 to 0.5 per cent. (unhardened) the quality (when the sponge was capable of being drawn out or welded) was unsurpassed in malleability and ductility. In fact, its peculiar satisfactory properties were such as to make any iron made by any other process practically inferior. It was impossible to say on working any charge or any bloom from a charge what the resultant weight or final quality would be. The reactions peculiar to the uncertain treatment by a native with but crude knowledge of the operation he was conducting were consequently erratic and irregular.

The method of refining iron sponge was, generally speaking, the same throughout India. The principle involved was the same—namely, the uniting or fusing of the very small grains with other or larger grains or shots of steely iron content in the sponge by kneading or balling together in a reducing atmosphere through an imperfect covering of slag. This operation often involved loss through oxidation by improper exposure to oxidising influences. A welding heat, however, was maintained on the charcoal hearth, and, at intervals, a large portion of the whole of the sponge was withdrawn and hammered, again refined, and again hammered, until a homogeneous wedge or rectangular piece was produced, which for heavier purposes was again welded with others and worked into requisite shapes.

The operative ability of the native made or marred the quality of his product. An expert smith, who ranked higher than a smelter producing the sponge, was aware of the difference between very hard steely iron and a softer one, and by careful selection of portions of his refined product would make an iron (although containing carbon) fit for hammering out in the cold to a dished or hollow shape, or an axe or kottar.

It was worthy of remark that Indian iron, possessing, as it nearly always did, varying small amounts

of carbon, was different from irons or steels produced by any other process. Its toughness, combined with softness, was very marked, and the metal generally possessed the characteristics of best Swedish charcoal irons and low-carbon steels. From close observation, he ventured to assert that the peculiar structure and composition of such metal, admitting of such excellent quality, was a strong argument in favour of considering whether or not we had therein another form of carbon other than the so-called combined and free or graphitic carbons; if not carbon, then of a peculiar unisolated carbide. If not this, perhaps the peculiarly useful properties were due to a total absence of nitrides or other deleterious combinations more likely to occur in metal produced by processes, direct or indirect, involving higher temperatures. He would suggest that this matter was worthy of research by metallurgists, especially in view of the superiority of cold-blast over hot-blast pig-iron, and similarly the superiority of steel produced from charcoal pig-iron over other kinds.

## British Foundrymen's Association.

### Annual Dinner of the Sheffield Branch.

The first annual dinner of the Sheffield Branch of the British Foundrymen's Association was held on Tuesday, March 5, Mr. Percy Longmuir, B.Met., President of the Branch, in the chair. About seventy members and guests were present.

Mr. W. H. Hatfield gave the toast of the "City and Trade of Sheffield," referring to the great changes which have taken place during the last half-century. New processes and new methods had been adopted in every branch of industry; the rule of thumb had been displaced by scientific control, and yet in spite of all these fundamental changes Sheffield and her industries had prospered wonderfully.

The Town Clerk of Sheffield (Mr. R. M. Prescott), who first responded, said the people of Sheffield were proud of their artizans and of their manufacturers, whose skill was responsible for the name of Sheffield being known the whole world over. At this moment, however, there was a great cloud hanging over the city and its trade, threatening our commercial enterprises and gripping far beyond the huge industries and into the very homes of every citizen in that great community. There could be no commercial prosperity where there was trade dislocation. With all this terrible uncertainty it behoved all of them to husband their resources. Probably there might be great lessons evolved from this period of depression which was overwhelming the country. It might teach more thrift, more care in the use of the very essentials of life; it might help them to practice a wise and rigid economy.

Mr. A. G. Capron, who also replied, said that when he came to Sheffield thirteen years ago the first thing that struck him was that the business of the city seemed to be so successful; there was a ring about it which seemed to show its success. He had worked in London for 19 years and everything seemed to be different; there was a note about the industries of Sheffield which he had not experienced in the great Metropolis. Continuing, the speaker dealt with the question of labour disturbances and the effect on industry.

Mr. T. H. Firth (Branch Vice-President) gave "The University of Sheffield," and referred to the work which was done by Mr. Mark Firth, Sir Frank Mappin, Sir Henry Stephenson and others making their Applied Science Department so excellent in every way. The metallurgical and engineering departments of the University were certainly to-day the finest in the world. (Applause.)

Dr. Ripper, Principal of the Applied Science Department of the University, in his response, first spoke of the value of the Foundrymen's Association to the trades of Sheffield. He referred to the growth of Sheffield University and to the increase of its influence. Their students in the Applied Science Department were engaged studying those sciences which would help to develop the industries in which they would be engaged. One of the things they studied was how to bring about economy and efficiency in the handling of the nation's resources. As to the generation of power, it was possible to generate power at a very low cost under some conditions, and at enormous cost under other conditions. In Sheffield the problem to-day was how to generate power at the lowest cost. If the cost of the unit of power could be reduced below what it was to-day it would be very much easier to introduce the electrical furnace into Sheffield industries, and that was one of the most pressing problems—how to supply the steel-worker with power at the lowest possible cost. The spirit of economy and efficiency was impressed on the student to-day because of the great importance of these matters. He was taught the importance of the infinitesimally small things; how tremendous the difference was between 0.1 per cent. of carbon and 1 per cent. He must know all the difference in these comparatively insignificant things. A small error in reasoning might lead to huge errors in the actual result. Alluding to past students, Dr. Ripper referred with pleasure to the fact that men who had gone through the Applied Science Department at Sheffield were to-day filling important positions in every part of the world. He believed the future of Sheffield was a great one; the work of societies like theirs supplemented by the University would make it great. (Applause.)

Mr. W. M. Gibbons, Registrar of the University, who also responded, referred to the bequests which Sheffield men had left to help on the great work which was being done by the University.

Dr. Manton proposed "The Sheffield Branch of the Foundrymen's Association."

The President, in his response, went back nine years to the time when half a dozen men met in a small room in a Birmingham Hotel, and there discussed the possibility of forming a British Foundrymen's Association. America had had her association for several years, and Germany had hers, and they felt that England should not be behind-hand in the matter. The response at first was not encouraging, but notwithstanding that, perhaps in the boldness of youth, they went forward, and their convention in Manchester although small in numbers, was enthusiastic in spirit. To-day the Association had a membership of 850, which exceeded the membership of either the American or German Associations. (Applause.) They were all animated by one spirit—to find out the reason why, to encourage one another in pressing forward knowledge in the vast field of the great unknown. (Hear, hear.) That the work had been successful could not now be denied, and those who were present at the Glasgow Convention would support that statement. (Hear, hear.) They had gone forward, but the progress they had made was as nothing to the progress which still had to be made. (Hear, hear.) When they thought of the fields yet to be explored, of the problems yet to be solved, they must feel humble.

The concluding toast of "The Visitors" was submitted by Mr. J. G. Crowther, and acknowledged by Mr. H. C. Elsb. An excellent musical programme was provided.

# Manufacture of Steel in the Girod Electric Furnace.

By Dr.-Ing. A. Mueller.

The Gutehoffnungshütte has recently installed a 3-ton experimental Girod furnace in their No. 1 Works for the purpose of electrically refining molten steel from their 25-ton open-hearth furnaces. The arrangement of the electrical conductors is of special interest, and Fig. 1 shows the method now in use. The advantages of this arrangement of the cables, from an electrical and metallurgical standpoint, are the following :—

(1) The electric arc circling about the periphery of the carbon electrode causes a strong agitation of slag and metal. This accelerates the speed of reaction between the slag and the iron bath, and therefore reduces greatly the time of refining.

(2) The arches of the roof as well as the furnace walls receive a more uniform radiation from the electric arc, and last longer.

(3) The saving in energy consumption is 10 per cent. as compared with the former arrangement.

(4) Copper bus-bars can be used instead of cables.

(5) The metal bath is heated uniformly throughout, and the resulting product is better.

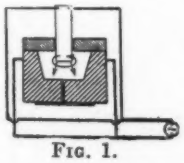


Fig. 1.

(6) Current interruptions due to the rupture of the arc are avoided, eliminating the resulting rushes of current on the motor-generator set and allowing an easier melting of cold charge than with methods previously in use.

(7) The consumption of the carbon electrode is more uniform than with the former arrangement, where one side of the electrode was consumed more quickly than the other, resulting in greater expense for electrodes.

In this new arrangement (Fig. 2) the six steel electrodes are electrically connected together by means of a copper ring and plate, and also with the furnace body. The entire current is conducted to the furnace by eight copper bus-bars, in parallel, which divide at the current distribution point US in such a way that opposite currents pass alternately along both sides of the furnace to the pivoting point.

Each bus-bar is connected by three cables (more recently by flexible copper bars) either with the furnace body or with the carbon electrode, as clearly shown in Fig. 2. This arrangement with the low voltage of operation overcomes insulation difficulties and has reduced induction currents considerably. The rotating magnetic fields around the electrode are uniform and very small.

For the first 225 heats the furnace was operated only during the day, and in many cases it was possible to tap the furnace five times in 12 hours under favourable conditions (see Fig. 3). In continuous operation it is possible, working day and night, to obtain 25 tons of steel from eight tappings.

Since the open-hearth furnaces were only tapped every four hours, the electric furnace could not be operated continually. About 3 tons of the metal tapped from the open-hearth was poured into a heated ladle on a weighing scale, and then charged into the electric furnace.

But this method was found to be too expensive, since the temperature drop of the charge from the open-hearth to the electric furnace resulted in a rather high fuel and energy consumption. It was, therefore finally decided to use a 23-ft. long launder which allows direct charging without any trouble. The weight of a charge can be adjusted with an accuracy of 400 lbs. by the eye or by a watch.

The operation of the electric furnace is in the main like that of the basic open-hearth furnace, the metallurgical reactions being essentially the same, except the deoxidation. During the charging process the current is 4,000 to 6,000 amperes; after the charging launder has been removed from the furnace by a crane, the amount of ore and lime required for the

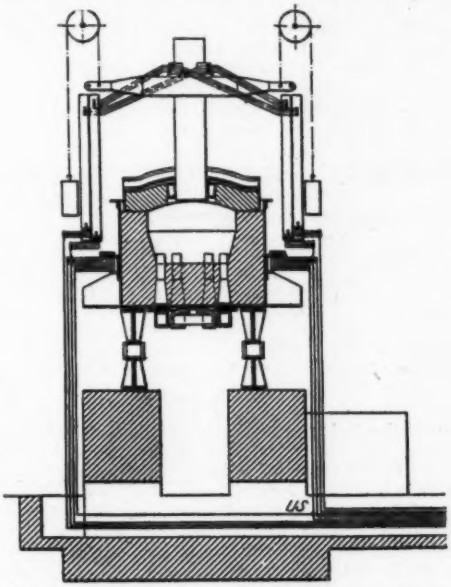



Fig. 2.—Section showing Details of New Arrangement.

metallurgical reactions is shovelled into the furnace.

The combustion of the phosphorus is now started by a gradual increase in the temperature, while simultaneously the amount of carbon still present is reduced down to a minimum by oxidation. A portion of the sulphur is also removed during this period. The period of refining by oxidation is, of course, the longer the higher the carbon and phosphorus content of the charge.

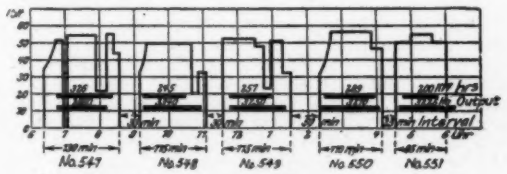



Fig. 3.—Furnace Operation in 12 Hours.

When this period is over, the oxidation slag is removed by tilting the furnace and the last traces of the slag are carefully scraped off. Then petroleum coke or carbon electrode remnants are added for recarburising and a deoxidation slag is formed by adding lime, fluor-spar, and ferro-silicon. The deoxidation and desulphurisation of the bath now pro-

* From "Stahl und Eisen."

ceed, and with proper operation a sulphur-content of 0.01 per cent. can be guaranteed. After complete refining, the tap hole is opened, the current cut off, the entire furnace with the carbon electrodes tilted 40 deg. from the horizontal, and the contents poured into a 4-ton ladle.

The lining of the furnace must be constructed and maintained with great care. The arches are chiefly subjected to destruction. With the new arrangement of the conductors, which has resulted in greater uniformity of heat radiation from the arc, and therefore greater uniformity of the wear and

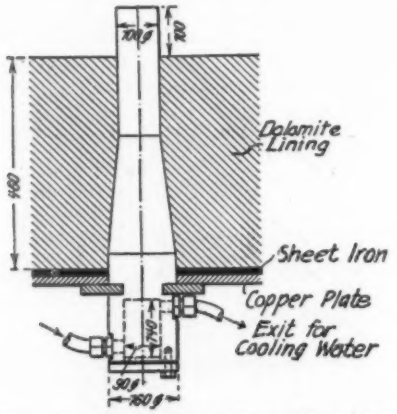



FIG. 4.— WATER-COOLED STEEL ELECTRODE.
(*Dimensions in Millimetres*).

tear of the lining, the silica roof with attached cooling ring will stand for 60 or 70 heats. The slightly-curved furnace roof of silica brick reinforced by iron bands is insulated from the side walls of the furnace by a thin layer of asbestos and a new roof can be substituted within 20 minutes.

It should be mentioned that the contact areas of the silica roof with its magnesite brick edge resting on the basic walls of the furnace do not reach such a high temperature as to make these materials so-called electrical conductors of the second class, which would result in leakage of the current. Moreover, the carbon electrode usually does not come in contact with the roof-cooling ring so that the insulation is only used as an additional safeguard. The hearth and walls were at first lined with magnesite, but dolomite is now used.

The ratio of the cross-section of the steel electrodes, which are embedded in the bottom of the furnace chamber, to the rest of the bottom area is 1 to 16. (See Fig. 4.)

A repair of the bottom does not become necessary until it is required to repair the walls. The walls are attacked strongest at the slag line, but the damage can be repaired between charges. After 120 heats the walls must be re-lined. The hearth bottom must also be repaired then, and filled up again to the original level, since it has meantime become about 2 in. deeper at the centre (where the temperature is highest) than at the periphery.

The cost of an entire dolomite lining is about £17 10s.; that of an entire magnesite lining £35. Dolomite has proved so efficient that it is now used exclusively. The total maintenance cost for the lining per ton of steel is about 1s. 2d.

Hearth-electrode cooling is still little understood, and has even been called a great drawback to the efficient operations of the Girod furnace. Fig. 4 shows that only that portion of the soft steel bars which projects below the furnace body is cooled by water, the bars being connected by a common pipe line.

The difficulty of maintaining the lining of the Girod hearth is also often exaggerated. The dolomite hearth rammed by compressed-air rammers has lasted through more than 1,000 charges, and has never given any trouble in spite of different lengths of heats and very different compositions of the charges.

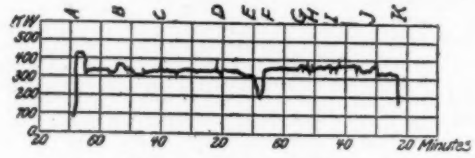



FIG. 5.—DIAGRAM OF POWER FLUCTUATIONS DURING A HEAT.

A = tapping. B, C, D = additions. E = carburisation. F = slagging. G = slag readily fluid. H = bath boiling. I = addition of ore. J = slag not fluid. K = charging.

It is calculated that the loss of heat due to the cooling of the carbon electrode is 3.65 per cent. of the total energy supply. The steel produced was 3,500 kg. (7,700 lbs.), so that 10.5 kw.-hours or 14.2 h.p.-hours were lost per ton of steel for cooling the carbon electrode.

The Girod furnace with one carbon electrode requires about 0.65 cubic metre of water per ton of steel for cooling the carbon electrode, which is equivalent to 9,000 calories. To cool the steel electrodes in the bottom the furnace needs 0.20 cubic metre of water per ton of steel, which is equivalent to 2,500 calories. This heat loss is insignificant when compared with the radiation losses attendant upon charging, slagging and tapping.

Further, the above figures show that cooling of the steel electrode requires only one-fourth of the amount

FIG. 6. — FLUCTUATIONS OF CURRENT WITH A HEAT IN THE FURNACE AFTER HAVING BEEN COOLED FOR 12 HOURS.

of water needed for the cooling of the carbon electrode.

If the water flows at the rate of 5 litres per minute (1.1 gallon per minute), an equilibrium condition is established in the heat exchange as soon as the bottom steel electrodes have melted down to a point which is 20 mm (0.8 in.) below the level of the hearth. These liquid pole points, which are gradually solidifying towards the lower end, have the composition of the steel bath to be refined. No chemical change is thereby caused in newly-charged metal, as they are emptied when the bath is tapped. The pits in the poles are then again filled with newly-charged metal. The effect of cooling is a uniform fusing of the pole points, and a homogeneous current density through the same.

On account of the uniform current density and the uniform heating effect of the electric arc, the bath is heated on the hearth surface and the upper layers in such a way that a sticking of steel in the originally cold corners of the hearth is soon eliminated.

The quiet melting of a cold scrap steel charge has been recognised as a great advantage of the Girod furnace. Figs. 5 and 6 give the fluctuations of the kw. consumption as plotted by a recording wattmeter.

starting with a liquid charge. The regulation of voltage and current is almost always automatic. Hand regulation (with the automatic regulator disconnected) is only used during slagging.

The furnace size, the length of intervals between successive heats, the cooling of the furnace during these intervals, the condition of the charge, the desired quality of the end products, and other matters can change the energy consumption very considerably. Fig. 7 shows the influence of the weight of charge in kilogrammes upon the specific energy consumption

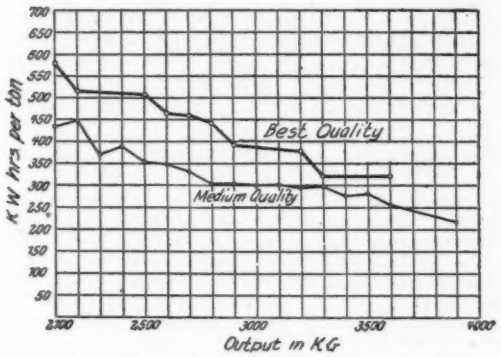



FIG. 7.—SPECIFIC ENERGY CONSUMPTION AS A FUNCTION OF THE WEIGHT OF THE CHARGE.

in kw.-hours per ton. The results are averages taken from 500 successive heats, including alloy steels. The energy consumption depends a great deal on the weight of the charge, and decreases in large furnaces.

The loss of heat through radiation and conduction, as also the fluctuations of temperature, decrease with the increasing size of furnaces. The temperature is much more easily regulated in larger furnaces than in smaller ones.

The minimum economical weight of charge is about 2,800 kilogrammes, and the specific energy consumption does not change materially with increasing weight up to 3,300 kilogrammes. (See Fig. 7.)

The specific energy consumption depends on the temperature of the furnace, and this again depends greatly on the length of the intervals between charges. Fig. 8 shows the decrease of the temperature after tapping, this decrease being very rapid com-

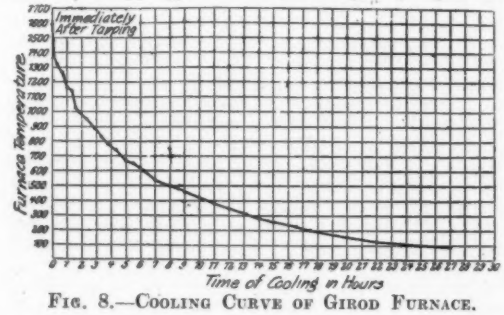



FIG. 8.—COOLING CURVE OF GIROD FURNACE.

pared with that of an open-hearth furnace. The temperature of the latter sinks down to 1,000 degrees C. after a 25-hours' pause, which cools afterwards at the rate of 20 degrees C. per hour. Under such conditions it is only possible to get a high thermal efficiency with the Girod furnace if it is charged, at the latest, 20 minutes after the last tapping. The interior of the furnace is then still at about 1,300 degrees C. The energy consumption per ton is then 188 kw.-hours for medium-quality steels, and 270 for high-quality steels.

Under very favourable conditions it was possible to refine 3,654 kg. (8,039 lbs.) of steel with an energy consumption of 158 kw.-hours per ton, including refining by oxidation, deoxidation, and desulphurisation. Large Girod furnaces are more favourable in this respect, as they can be charged immediately after tappings, *i.e.*, while they are at a temperature 200 degrees higher.

Fig. 9 is a diagram of the chemical reactions during a heat in the Girod furnace, and illustrates the changes of the carbon, manganese, phosphorus, sulphur, and silicon contents.

The removal of the sulphur takes place in three different ways. The following is given by the author as an example of a heat:—

TABLE I.—HEAT E 744.

| | Sample No. | C Per cent | Mn Per cent | P Per cent | S Per cent | Si Per cent |
|---|---|---|---|---|---|---|
| *Oxidation period.* Charge ... ... | 1 | 0.09 | 0.54 | 0.020 | 0.042 | trace |
| After adding 10 kg. ore ... ... | 2 | 0.09 | 0.44 | 0.016 | 0.037 | ,, |
| After adding 15 kg. ore ... ... | 3 | 0.09 | 0.34 | 0.010 | 0.037 | ,, |
| Sample just before slagging ... | 4 | 0.09 | 0.28 | 0.005 | 0.033 | ,, |
| *Deoxidation period.* After adding: | | | | | | |
| 22 kg. coke, 60 kg. refining slag... | 5 | 0.49 | 0.20 | 0.005 | 0.037 | ,, |
| 40 kg. refining slag ... .. | 6 | 0.53 | 0.21 | trace | 0.037 | ,, |
| 2 kg. ferro-silicon, 20 kg. refining slag ... .. ... ... ... | 7 | 0.48 | 0.21 | ,, | 0.035 | ,, |
| 12 kg. ferro-silicon, 18 kg. ferro-manganese... ... ... ... | 8 | 0.54 | 0.75 | 0.013 | 0.022 | 0.20 |
| 1 kg. powdered lime .. ... | 9 | 0.52 | 0.70 | 0.010 | 0.021 | 0.22 |
| 1 kg. powdered petroleum coke | 10 | 0.52 | 0.70 | 0.010 | 0.023 | 0.21 |
| 3 kg. ferro silicon ... ... | 11 | 0.57 | 0.71 | 0.012 | 0.018 | 0.26 |
| Final sample ... ... ... ... | 12 | 0.58 | 0.70 | 0.015 | 0.014 | 0.21 |

Final product, 2,985 kg. electric steel.
Charge, 3,030 kg. soft steel.
During the refining period by oxidation sulphur was removed as follows:

| | |
|---|---|
| 3,030 kg. charge (0.042 p.c.S) contain ... | 1,273 grammes S |
| 3,030 kg. (0.033 p.c.S) just before slagging contain ... ... ... ... ... | 1,000 ,, |
| Sulphur removed ... ... ... ... | 273 grammes S or 21.4 % |
| After slagging 3,030 kg. steel (0.033 p.c. S) contain... ... ... ... ... ... | 990 grammes S |
| Absorption of sulphur from 22 kg. petroleum coke with 0.60 p.c. S ... ... | 132 ,, |
| Sulphur in metal bath ... ... ... | 1,122 grammes S |
| At the end of desulphurisation period (0.014 p.c S) .. ... ... ... ... | 420 ,, |
| Removed from metal bath .. ... | 702 grammes S |

For the production of a deoxidation slag there were added:

| | |
|---|---|
| 80 kg. lime with 0.08 p.c. sulphur ... | 64 grammes S |
| 30 kg. fluorspar with 0.07 p.c. sulphur | 21 ,, |
| 10 kg. sand with traces of sulphur | traces ,, |
| 3 kg. ferro-silicon with traces of sulphur ... ... ... ... | traces ,, |
| The deoxidation slag contains ... | 85 grammes S |
| 135 kg. final slag with 0.5 p.c. S ... | .. 675 ,, |
| The slag has therefore absorbed from the bath ... .. .. ... | 590 grammes S |
| There were removed from the bath ... | 702 ,, |
| Missing ... ... ... ... ... | 112 grammes S or 16% |

(1) During the oxidation period sulphur is removed through the action of the slag rich in ferrous oxide; sulphur dioxide is formed which escapes.

(2) In the deoxidation period the white slag, free from ferrous oxide, removes sulphur.

(3) The third agent in desulphurisation is silicon, forming silicon sulphide.

It is now generally believed that oxides, gases, and slag enclosures have a much more unfavourable influence on the physical properties of steel than phosphorus and sulphur below 0.02 per cent. The electric steel furnace allows the steel bath to rest a long time under the neutral non-oxide slag, which procedure can only be carried out in the crucible with difficulty

without chemical changes, and cannot be carried out at all in the open-hearth. The possibility of removing the oxides, gases, and slag enclosure in this way is, therefore, an important advantage of the electric furnace.

As regards deoxidation, it might be said that it is started by introducing carbonaceous materials. The extent and the speed of deoxidation depend on the

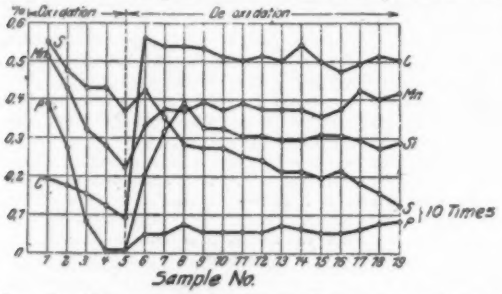



FIG. 9.—DIAGRAM OF CHEMICAL REACTIONS DURING A HEAT, SHOWING CHANGES OF C, MN, SI, S AND P IN 19 SAMPLES OF METAL.

temperature, the amount and the action in time of the carbon additions. Complete deoxidation of steel with the aid of carbon alone (even with a slag completely free from ferrous oxide) is possible in the electric furnace only, if the refining period is extended for a very considerable time. It is, therefore, advisable to remove the last traces of oxygen by the use of other deoxidation agents like manganese and silicon in order to bring the oxygen into the slag. The oxygen compounds in the slag are reduced by the aid of ferro-silicon or powdered charcoal.

## The Hering "Pinch Effect" Furnace.*

BY E. KILBURN SCOTT.

The "pinch phenomenon" was first noticed in connection with electric furnaces by Mr. Carl Hering, and he discovered the phenomenon when working on a furnace in which it was a distinct disadvantage to have it. He therefore set to work to find out how it could be made useful, and the result has been the further discovery of a valveless electro-magnetic pump.

It may be interesting to note that when in Sydney the writer saw a metal pipe which had been struck by lightning. The great inward pressure due to the current travelling along the pipe had completely collapsed it. It was not simply flattened, but had crinkled all round. Again, about ten years ago, when making calcium-carbide, he noticed that the blocks always came out of the furnace smaller in section at the middle than at the ends.

*Refractory Lining.*—As the hottest metal flows up the centre of the resister tube, the lining does not have to withstand great heat. Again, there is very little eroding action due to friction on the wall, because the pinch effect tends to pull the metal away from the lining; indeed, it tends to form a vacuum there. This is just the opposite to some furnaces, where the circulation of the molten metal has given trouble by eroding the lining.

For the lining, calcined magnesite powder is employed; it is packed in whilst in plastic condition, and forms an extremely hard and smooth glossy surface after being heated. Electrically-fused magnesite, which was first made by the writer on a large scale ten years ago, and suggested by him as a furnace lining, is to be tried.

*Action of Slag.*—The rapid circulation obtained in the furnace allows chemical changes to take place rapidly, and this means great economy in time. The maximum temperature at any point does not need to be much above the normal. In other furnaces where circulation is sluggish the temperatures in the charge vary a good deal. To allow for effective action of the slag it is important that the hottest metal should impinge directly on it. This is just exactly what takes place in the Hering furnace, for when it leaves the centre of the tube, the heated metal is forced up against the blanket of slag. Reaction with the slag is an essential factor in many processes.

*Power Factor.*—It should be noted that the furnace will work with either direct or alternating current, because the direction of flow of the liquid in the resister tube is independent of the direction of the current. The pinch effect is also the same. Three-phase currents can be used, there being then three electrodes instead of two. With alternating current the power factor can be very high indeed, practically unity, and in this respect the Hering furnace is sharply marked out from induction furnaces which have a low power factor. It is true that the power factor of the latter may be 0.7 to 0.8 with 25 cycles, but only by using some extraneous and expensive device, such as an over-excited motor-generator. Again, the frequency can be anything that is used in everyday practice; it need not be specially low.

*Excessive Pinch Effect.*—One criticism that has been made is that the pinch effect may be too great and the continuity of the liquid conductor be broken. This, however, is only a matter of correct proportioning of the size of the resister tube and the amount of current. It may be mentioned that Mr. Hering has several times allowed the metal in the resister tubes to cool and harden overnight, and then found that he could start up next day from the cold state. This showed that the metal had not broken apart in shrinking. Some metals pinch off more readily than others. For example, aluminium, because it is light, pinches off with a current only a little higher than that required to melt it. But this only means that greater care must be exercised in proportioning the electrodes and in the smelting.

*Shape of Furnace.*—One feature which above all others should appeal to iron and steel makers is that the furnaces are very little, if any, different from those to which he has been accustomed. Hitherto, electric-furnace working has been handicapped by the unusual, not to say complicated, designs which engineers have put forward. This objection cannot be brought against the Hering pinch-effect furnace. So far as heat loss is concerned, a section of a sphere gives the smallest area from which heat can be radiated. A square-shaped bath is next, and the rectangular shape a bad third. But the worst form of all is the long, winding, narrow channel of the induction furnace. Considered as a furnace or from economy of heat point of view, surely nothing could be worse.

*Advantages of the Hering Furnace.*—(*a*) It is simple and cheap, consisting merely of two electrodes in an ordinary furnace hearth. (*b*) The heat is generated by resistance in the charge itself and the heating takes places at the bottom of the bath, where most effective. (*c*) The circulation of the hot charge is automatic and most effective, namely, from the bottom of the bath up to the underside of the slag. (*d*) For a given size of furnace hearth and given amount of electric energy, a larger amount of material can be

* Abstract of a Paper read before the Faraday Society.

dealt with per day. (*e*) The electrodes are of metal and do not consume away, as is the case with carbon and graphite. (*f*) The temperature and circulation of metal may be exactly adjusted to metallurgical requirements. (*g*) Gaseous fuel heat can be applied to the top of the bath without affecting the electrical gear. Current can be switched on for the refining part of the process. (*h*) The electrical gear is out of the way on the underside, and where the furnace is required to tilt, a transformer can be attached to it. (*i*) Only part of the charge conducts the current, so that the volume of a charge may vary considerably without affecting electrical conditions.

*Disadvantages of Arc Furnaces.*—(*a*) Carbon or graphite are costly and burn away quickly. They sometimes also break off in lumps, and there is the possibility of wasting away at the sides. (*b*) The electrodes must be fed forward as they burn away, and this requires special gear. (*c*) There is a difficulty in getting continuous working owing to changing carbons, and making good electrical connections. (*d*) Quite frequently there is trouble in providing for water cooling, also a chance of water leaking into the furnace. (*e*) The heat is applied at the top of the charge and thus has to travel down by slow conduction and agitation of the charge. Slag at the top may interfere with free working. (*f*) The temperature of the arc is frequently greater than that necessary for metallurgical requirements. (*g*) The furnace has to be larger than necessary to provide space for the carbons.

*Disadvantages of Induction Furnaces.*—(*a*) Expensive, and the design not convenient from a metallurgical point of view, the electrical gear being in the way and near to the hot metal. (*b*) The transformer must necessarily be inefficient and work at a low power factor. (*c*) The necessity of retaining a large part of the charge to start the next run, or else preheating the charge, is troublesome. (*d*) The temperature may be limited by reason of the pinch phenomenon. The maximum temperature may thus not be high enough, as for aluminium, which on account of its lightness pinches off very readily. (*e*) Owing to the restricted nature of the channels there is no large open space for slag action.

*Disadvantages of Ordinary Resistance Furnaces.*—(*a*) There is a serious limit of temperature and speed of heating due to the pinch phenomenon. (*b*) There is a possibility of contamination of the product by the carbon or graphite electrodes. (*c*) There are great changes in current as the quantity of reduced material increases. (*d*) The slag surface is small, or if this is provided by an additional hearth, there is difficulty in getting circulation from the heating channel to the hearth. (*e*) The application of three-phase leads to complication.

Mr. Carl Hering (Philadelphia, U.S.A.) wrote that, concerning Mr. Kilburn Scott's interesting observation in the calcium-carbide furnace, he thought it was very likely that the peculiar shape was due to the same force, as it was quite a powerful force under proper conditions, and would be quite likely to give a plastic conductor such a shape. He had melted steel without any difficulty, and obtained it very liquid; this, in fact, was easier than most of the other metals and alloys, as the proportions were better for steel than for those lower resistance alloys. He had, therefore, been carrying out his tests under far more unfavourable conditions than those for the industrial application for steel.

In melting steel, a carbon rod held in front of one of the squirting tubes dissolved like a stick of candy in hot water; on the other hand, iron ore placed on this carbonised iron gave off enormous volumes of gas, showing that the ore was being reduced by the carbon in the iron as was done in the open-hearth process. He was glad Mr. Kilburn Scott had emphasised that the furnace will appeal to the ordinary steel-makers as it will enable them to use furnaces that they have been accustomed to. This he also appreciated, and he called attention to the fact that his furnace could be added to the existing open-hearth furnaces to advantage. The feature which seemed to appeal most strongly to all practical steel-makers, and which they had expressed to him repeatedly, was the thorough mixing.

Concerning a question as to the largest size furnace yet used, he could only say that he had at present been experimenting only with rather small ones, but he was now negotiating with parties for large ones, and would probably soon have some in operation. He had had to determine many constants in order to design a larger one properly. Among these was the electrical resistivity of steel and other alloys, the data for which did not exist. For these experiments special furnaces had to be built and then pulled down after the constants were determined, in order to determine others. This took much time, as every furnace must be dried out. At present he had in hand the construction of several one- and five-ton furnaces, and even a 10-ton furnace, to be operated on a commercial scale. Regarding the sizes of the resister tubes, there were, of course, an infinite number of sizes which could be given to the resisters for a given furnace, and it was therefore impossible to give any fixed sizes. Nor would it be well to publish any such sizes, as others might then experiment with them, and, not knowing the properties of the furnace, might make failures and then blame the furnace. For a furnace of one ton, however, the resister tubes would probably be two to three inches in diameter. Their size also depended greatly on the resistivity of the steel, and the value of this was only known approximately.

## Refractory Materials for Electric Furnaces.

For many purposes, as is well known, magnesia is an excellent refractory material, but it has also serious faults. The worst of these is an objectionable way of cracking when heated to a high temperature. This is, no doubt, in large part due to the remarkable way in which magnesia articles shrink when heated to high temperatures, corresponding to the increase in the absolute density. It is obvious that the tendency to cracking exhibited by the ordinary calcined magnesite is less likely to be found in a material which has been calcined at the very much higher temperatures attainable by electrical means. Several tons of magnesia have been electrically calcined and tested in a great variety of furnaces, and in every case excellent results have been obtained. There is one important point to note in regard to this highly calcined material. The ordinary calcined magnesia absorbs carbon dioxide gas, forming magnesium carbonate more or less rapidly, but this does not occur at all, or with extraordinary slowness, in the case of the electrically calcined product. In the preparation of this magnesia it is possible to use an arc furnace, but the method is not altogether satisfactory on account of its cost. It is unnecessary, and, in fact, disadvantageous in many ways, to fuse the magnesia. Accordingly, a resistance furnace has been designed, which will calcine the magnesia to the desired degree. In regard to lime, some hundreds of pounds have been fused in the electric furnace, and it appears that in this form it is a much better conductor of heat than ordinary quick-lime. Blocks cut from the fused product stand heating, followed by sudden cooling, very well. Fused lime resists exposure to moist air remarkably well, for while it will eventually slack, this is a process of days instead of hours. Even when boiled with water, hydration proceeds very slowly.

# Foundry Plant and Equipment.

## The Osborn Spark Arrester.

A cupola blowing direct to atmosphere must always be a source of more or less danger, depending upon its particular surroundings, as the sparks therefrom can and do travel considerable distances in a live condition. But quite apart from this element of risk, the use of the open-topped cupola entails a constant labour in clearing the deposit of dust from the gutters of the works. It may at once be said that any apparatus which successfully arrests the sparks must also intercept the dust, though its efficiency in this direction is entirely dependent upon the particular design of the apparatus and its method of application. An apparatus may deal successfully with the sparks and heavier particles without of necessity intercepting the finer dust which is the chief source of the trouble on the roofs. There is, at present at any rate, no commercially practicable means of entirely preventing the egression of this fine dust, but with the application of a suitable form of arrester, it may be reduced to an almost negligible quantity.

THE OSBORN SPARK ARRESTER FOR CUPOLAS.

Of the number of such arresters previously upon the market, that known as the tank form has, on the whole, proved the most effective. This, as no doubt most of our readers are aware, consists of a water-filled vessel, into which sparks and dust are deflected by means of a baffle arranged on the top of the flue. Such an apparatus, however, ceases to be effective when there is any tendency to force the cupola, whilst the tank must be frequently cleaned out, for it should be borne in mind that, on an average, a ton of dust will have to be dealt with for every hundred tons of iron brought down, and it is not always possible to place such tanks in an easily accessible position.

It is obvious that the simplest solution of the problem is to deal with the dust in a dry state, and as the essential portion of the apparatus must be more or less removed from easy access, it must be simple alike in design and construction, and possess a useful life equal to that of the cupola itself. These requirements appear to be particularly well met in the Osborn spark arrester, of which the manufacturers are Messrs. T. Davies & Son, Railway Iron Works, West Gorton, Manchester.

Some few months ago Messrs. Entwisle & Kenyon, Limited, Accrington, Lancs., erected a wood-working and French-polishing shop, and as this adjoined their foundry, it necessitated not only the checking of sparks for purposes of safety, but also, so far as practicable, the emission of dust from the cupola. For this purpose it was decided to adopt the Osborn spark arrester. The installation, which is illustrated herewith, has now been in operation for some months, to the entire satisfaction of the works management.

The arrester, which was briefly described in our issue of May, 1910, consists of a firebrick-lined flue bent over in the form of an arch and attached at one side to the top of the cupola by means of an iron angle ring, and on the other side continued in the form of a shoot, which, given an angle of about 60 degrees, terminates, cart high, in the foundry yard, the opening being closed by a sliding door. On the top of the arch an opening is provided for the escape of the gases, at the side of which opening nearest the cupola is a durable firebrick baffle, which extends about half the depth of the flue. The fluing particles impinging on this baffle are thrown downwards and carried forwards into the continuation of the flue, which forms the collector.

At the time of our representative's visit, this collector was being emptied, a cartload of dust being removed as the result of three weeks' work.

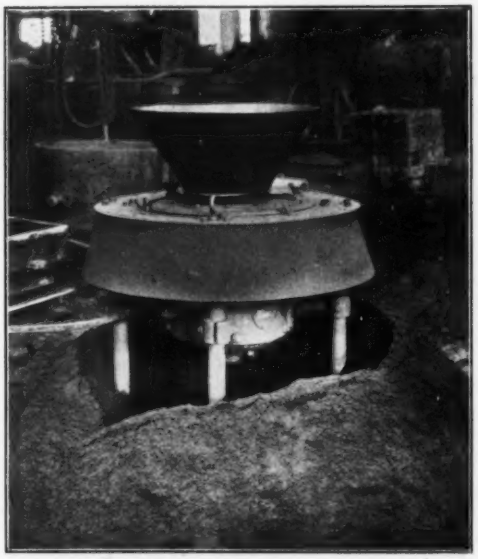
A particularly noticeable feature of the discharge was the large percentage of fine dust, which made its presence unpleasantly evident, but at the same time graphically demonstrated the efficiency of the apparatus.

It will be noted from our illustration that the arrester is of larger diameter in the body than the cupola top. This is not a usual arrangement, but was adopted to meet the special conditions, as the cupola is coned down considerably from the charging hole. Generally speaking, the diameter of the arrester is similar to that of the cupola top, but this, as also the depth of the baffle wall, must be governed by conditions, the main factors being the particular construction of the cupola, its height and, to a lesser extent, the pressure at which it is blown. Of course, the shallower the baffle wall can be kept, consistent with doing its work, the better will be the output results of the cupola, due to the reduction of back pressure and the throttling effect on the gases, though our representative was informed that the back pressure from the apparatus in question (and in this case it will be noted that the flue is baffled for half its effective area, probably an extreme case) was too trifling for consideration. The cupola is blown at from 14 in. to 15 in. water gauge.

The most economical and convenient application of the Osborn arrester would be where, as is now the usual practice, two cupolas are set side-by-side and working alternately. In such case each cupola would have its baffle wall built into the centre of the arching, and in operation the uptake of the standby cupola would act as the downcomer to the blowing cupola. The dust collected could then be removed at any convenient point; for example, a damper might be fixed across the cupola at the charging hole, which would leave the body free for carrying out any necessary repairs.

## The Oerlikon Centrifugal Disintegrator for Moulding Sand.

In the preparation of moulding sand it is essential that all lumps and aggregations should be broken down, so as to separate the grains and furnish a material that is plastic and permeable by the gases liberated in the mould; and foreign particles, especially those of iron, usually present in material that has been used before, must also be eliminated. A centrifugal machine for achieving these objects

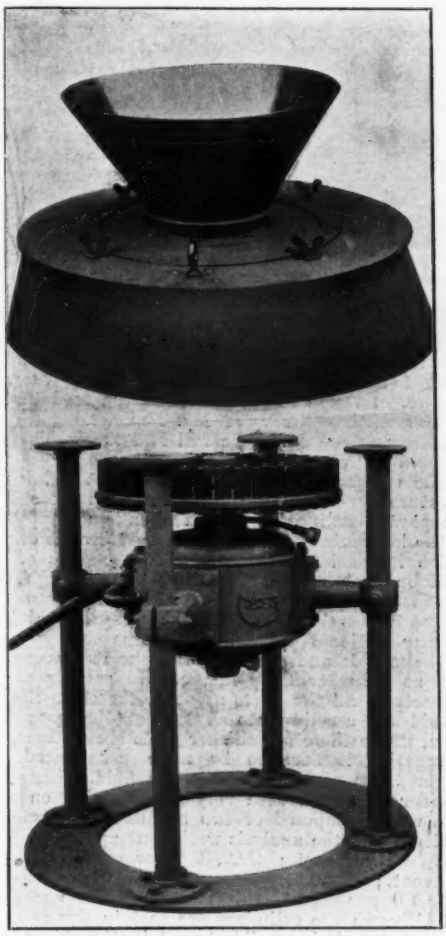


THE OERLIKON CENTRIFUGAL DISINTEGRATOR FOR MOULDING-SAND.

has been in use for some time in the foundry of the Maschinenfabrik Oerlikon, and has recently been put on the market.

As shown in the accompanying illustrations, the frame of the machine is formed of four pillars bolted on to an iron base ring; and these pillars support the outer casing, which consists of a circular cover plate, carrying a feed hopper and supporting a wide conical flange, which extends downward and acts as a shield to prevent dispersion of the sand treated in the machine. Below this hood, which is easily detachable, is mounted a vertical electromotor, completely enclosed in a dust-proof casing and secured on the pillars by bolted cross arms. Keyed on to the upper end of the motor shaft is a horizontal disc, provided in the neighbourhood of its periphery with three concentric rows of staggered pins of circular cross-section.

The motor (polyphase or direct-current, as required) is connected with an electric-lighting circuit by means of a suitable length of cable. The sand shovelled into the feed hopper is flung outward radially by the centrifugal force against the rows of pins, between which it passes, to fall down against the flange of the hood in a finely-divided condition on to the floor, where it accumulates in an annular heap, and can then be removed for use. Any particles of iron in the sand will collect in the middle of the horizontal disc and in front of the rows of pins, whence they can be easily removed after the cover is taken off. Lumpy sand is broken down into its constituent grains.



SHOWING CONSTRUCTION OF THE OERLIKON CENTRIFUGAL DISINTEGRATOR.

The sand delivered by the machine can be used direct for moulding machine parts and plates without any further screening or other treatment, thus rendering the employment of expensive moulding sand superfluous. The moulds of this sand give clean, compact castings, which require but little fettling, if any. Where various grades of sand are placed simultaneously in the hopper, perfect admixture is ensured.

An ordinary 2 h.p. motor, to run at about 960 revolutions, is provided, though for ordinary conditions one of lower power is sufficient. Motors for different kinds of current and voltage can be sup-

plied to suit requirements. The machine is able to deal with as much sand as two or three men can keep on shovelling into the hopper—that is to say, about 6 to 10 cwt. per minute. In comparison with hand screening, this implies a saving of about 50 per cent. in wages. The machine is specially adapted for foundries producing small castings in large quantities. No special foundation is needed.

The advantages claimed by the makers include stability and compact construction, reliability in working, convenience of carriage, and erection without foundation or shafting, production of fine, loose sand free from extraneous substances, and ready for immediate use, low cost of repairs, convenience in management and cleaning, large output at small working cost, and considerable saving in wages. The complete machine weighs about 5½ cwt., and measures about 4 ft. in height by 3 ft. across.

## Correspondence.

### Casting Temperatures of Cast-Iron.

*To the Editor of the* FOUNDRY TRADE JOURNAL.

SIR,—Replying to Mr. G. Hailstone's remarks on my idea of casting temperatures, it would appear that I only had in mind how to keep the sides square. I failed to say that I should feed the particular casting cited. If Mr. Hailstone will study the feeding rod curve, he will find the inside would be solid as well.

The contention that pouring iron at a low temperature renders the combined carbon more liable to separate out into graphitic carbon is not applicable in the low carbon, silicon, manganese brands of iron, which in good practice would be the class of iron used on such a heavy casting. With high total carbon and relatively high silicon it would be different, but then the class of castings would be of thinner sectional parts, and also the cooling action of the moulds and cores would make it necessary to cast at a higher temperature. No casting of any size sets in all the parts at once, therefore there is a fluid and a solid state at one and the same time. Then, where there are thicker walls than others, the segregation is sure to be more pronounced, the longer those particular parts are fluid. There is a cylinder iron used with very good results on high-class work, composed of two brands run down once to blend, and the analysis works out approximately: G.C., 2.4 per cent.; C.C., 0.6 per cent.; Si., 1.23 per cent.; S., 0.07 per cent.; P., 0.9 per cent.; Mn., 1.0 per cent. This mixture melts very hot, and although the cylinders are cast in dry sand, if run as hot as it is possible to get it, the skin of the casting, to use a moulder's phrase, is rough as it can be. The dirt will perhaps cause a weakness if lodged in some particular place, and as there is just as much chance of making a waster with casting metal at such hot temperatures as at too low a temperature, pouring at the temperature experience has shown to be the best for the job in hand will give better returns both in castings and financially (chief item).

As regards the casting of test bars, as hot as possible is best, I admit; but the unfaithfulness of test bars is notorious.

Yours, etc.,

J. PEERS.

### Special Elements in Cast Iron.

*To the Editor of* THE FOUNDRY TRADE JOURNAL.

SIR,—I have read with interest your report in the March issue of the lecture delivered by Mr. J. Kent Smith on "Vanadium in Cast Iron," and although having been instructed considerably thereby, am still in doubt as to the advisability of using such special elements as vanadium in general work. For special work, too, I must confess to a preference for mixtures which in the past have given satisfaction, though experiments showing an advantage, in keeping with the cost of same, obtained by the use of vanadium might do much to dispel a prejudice (admittedly a prejudice and not an objection based on extended experience) against the use of the "medicine chest" in the foundry, which is by no means rare in this country. We all know of bad irons—irons that could be improved considerably; but we don't generally apply them for purposes where good castings are wanted. There is not much difficulty in this country obtaining mixtures that will meet all reasonable specifications, and there is thus little inclination to dabble in "additions" that are at least somewhat uncertain so far as the average foundryman's experience goes. There appears to be in America a predisposition to try the effect of medicines—as is it that there is so much more room for improvement even in the better irons; the experience of Mr. Cook as regards strength tests would rather suggest the latter. At the same time, when such an authority as Mr. Kent Smith suggests the wide possibilities put forward in his lecture, the subject is not to be dismissed with a cursory glance. We all know what marvellous results have been attained by the addition of vanadium to steel, and if the same element can, at a reasonable cost, confer even comparatively much smaller benefits on iron, most founders would probably be open to include it in their "medicine chest."

Yours, etc.,

"A. McQ."

## Queries.

### Melting Loss in Aluminium Casting.

Can any reader say what should be the average percentage loss in melting and casting a commercial aluminium alloy containing Al. 88 per cent., Cu. 2 per cent., Zn. 10 per cent.?

(1) What is the percentage loss in weight of a mixture as above made from new metals, melted in 100-lb. crucible in coke fire?

(2) What is the percentage loss in weight of alloy as above, taking the ordinary week-in, week-out working of a jobbing foundry, which includes remelting of risers, etc.

"E. P."

### Difficulties with Malleable Iron Castings.

I have considerable difficulty in getting delivery of malleable cast-iron wheels with arms, and the excuse always given for the delay is that these wheels have to go through a double process of annealing. But even with this extra precaution there is still a large percentage of breakages. I have no desire to remove my patterns, for various reasons, and for my own information I should like to know if other founders have the same trouble with malleable castings such as wheels with arms, or other castings where the metal is of unequal thickness. Perhaps some of your readers can oblige me with this information?

"Constant Reader."

# Inventions.

## Applications for Patents.

An asterisk indicates that a complete specification accompanies the application. When inventions are communicated the names of the communicators are in brackets.

3,872. Means to be employed in casting moulds. I. Butler.
4,258. Cores for foundry work. C. Morehead, H. B. Watson, J. S. Watson, R. Christie, and E. T. White, trading as Henry Watson & Sons.
4,287*Collapsible cores. A. Adamson, Rockey and H. Eldridge.
4,446.*Heating-furnaces. W. Anderson, J. Meikle, and C. W. Fulton.
4,565. Sand-moulding machines. S. Strettles and A. C. Russell.
4,594. Preparation of moulds and casts. W. Winans.
4,692.*Method of purifying metals. A. G. Sundberg.
4,869.*Moulding-machines. E. M. Pridmore and H. A. Pridmore.
4,989.*Furnaces for melting, smelting, refining, etc. S. W. Price.
5,037. Moulds for the production of metal castings. Thomas Holcroft & Sons, Limited, and A. Holcroft.
5,519.*Treating cast-metal ingots. J. C. Russell.
5,799.*Centring pins for moulds. P. Valerius.

## Abstracts of British Patent Specifications recently accepted.

25,581 (1910). *Manufacture of Iron and Steel.* Elektrostahl Gesellschaft mit beschränkter Haftung, Remscheid-Hasten, Germany.—This invention consists of a process for improving the quality of liquid malleable iron and steel, which comprises covering the same on an acid or basic hearth with a slag containing a metallic oxide, for the purpose of providing the metal with dissolved oxygen, heating the metal and simultaneously adding to the molten metal at intervals throughout the treatment by the slag a solid substance containing free carbon, so that dissolved oxygen and dissolving carbon may be simultaneously active within the metal throughout the process. The process may be carried into practice as follows:—(a) Iron which has been melted in, or is placed in a liquid condition in an acid furnace, is covered with the slag and fed at intervals with carburite, *i.e.*, a mixture of metal and carbon brought to a solid state. It is then heated for a certain time, ascertained by experience, and then, after introducing any desired additions of silicon, manganese or alloys, is tapped and cast. (b) Similar iron, in a basic furnace, is covered with a slag composed of about 40-50 per cent. lime, 20-25 per cent. fluor-spar, and 30-35 per cent. iron ore, and fed at intervals with carburite. In the basic furnace, treatment with a slag free from oxidised iron may precede the operation for the purpose of eliminating sulphur.

241 (1911). *Process for Covering Iron and Steel Articles with a Rust Proof Coating.* G. Bauer, 16, Cölnerstrasse Düsseldorf, Germany.—The treatment of files is taken as an example of the application of this patent. After cleaning the files by means of the sand blast they are placed in a solution of oil soluble in water. This is made by a mineral oil formed into an emulsion in the usual way, using any known soap. The oil is then fully soluble in water. A solution of it in water of about one part of the oil to 20 parts of water is made, and the files placed in the solution. After treatment they are removed to the drying oven until the tang is dried, whilst the surface may still be wet. The tang is then annealed by dipping it into liquid lead, and then the files are immediately plunged into a second solution, consisting of about one part of oil soluble in water and two to three parts of water. After allowing the superfluous solution to drop off, the files are ready for packing.

# Trade Talk.

We understand that an Engineers' Club has been suggested for Manchester.

Vickers, Limited, have been elected members of the British Chamber of Commerce in Paris.

Mr. W. J. Axford has acquired the business of the late Mr. J. Axford, ironfounder, Truro.

Alfred Herbert, Limited, of Coventry, have opened offices at Atlas Chambers, King Street, Leeds.

Ransomes, Sims & Jefferies, Limited, have removed their London offices to Palmerston House, 34, Old Broad Street, E.C.

The Detroit Engine Company, 181, Gamage Buildings, Holborn, E.C., have removed to 94, Hatton Garden, London, E.C.

The name of the Glasgow and West of Scotland Technical College has been changed to the Royal Technical College, Glasgow.

Messrs. H. B. Barnard & Sons, metal merchants, of 114, Lambeth Walk, London, S.E., have removed to Glyn Street, Lambeth, S.E.

The Hurst Iron Works Company, Limited, of Princess Chambers, Wolverhampton, paid a first dividend of 9d. in the £1 on March 7.

Robert Bowran & Company, Limited, Newcastle-on-Tyne, have opened offices at 21 and 22, Mark Lane Station Buildings, London, E.C.

The Keighley Gas an Oil Engine Company, Low Street, Keighley, are establishing a branch at 97D, Queen Victoria Street, London, E.C.

The Chinnery Engineering Company, Limited, is being wound up voluntarily, with Mr. H. D. Sheldrake, 12, Duke Street, Chelmsford, as liquidator.

The Coventry Ordnance Works have almost completed their first set of the heaviest naval gun mountings, and have secured orders for two additional sets.

Messrs. Hall & Hall, 47, Leadenhall Street, E.C., have been appointed London agents of Messrs. Ritchie, Graham & Milne, engineers and shipbuilders, Glasgow.

Mr. Max Noelle, consulting engineer, and the representative of the Deutsche Maschinenfabrik A.G., of Duisburg, has removed his offices to 36, Victoria Street, Westminster, S.W.

The partnership heretofore subsisting between Messrs. H. Heaton & E. Hartley, carrying on business as machine tool makers, at Empress Works, Riddlesden, Keighley, has been dissolved.

The Earl of Dudley's Round Oak Works, Limited, have opened an office at 104, West George Street, Glasgow, and have appointed Mr. H. Hampton Vick as their representative.

T. Rowlands & Company, Limited, steel manufacturers and alloy merchants, Stirling Chambers, Campo Lane, Sheffield, have removed to Palm Tree Works, Staniforth Road, Sheffield.

Mr. C. D. Phillips, J.P., of the Emlyn and Central Engineering Works and Foundry, Newport, gave a demonstration at his works on March 18 of a portable oxy-acetylene welding plant.

Mr. S. Cowper-Coles, 1 and 2, Old Pye Street, Westminster, S.W., has introduced a new electrolytic process for coating metallic surfaces with lead to any desired thickness, up to ¼ in. or more.

Messrs. W. Abell, A. E. Seymour, and J. Skidmore, carrying on business as brassfounders, at 91, Bridge Street, West Hockley, Birmingham, under the style of Brown & Seymour, have dissolved partnership.

A receiving order has been made in connection with the affairs of H. Simmonds, brassfounder, of New Charles Street, Goswell Road, and 43, Hull Street, City Road, London, E.C., who traded as F. H. Simmonds.

At a Meeting of the Sheffield Society of Applied Metallurgy, on March 1, Mr. Percy Longmuir gave an interesting address on "Casting Temperatures of Non-Ferrous Metals." Professor Arnold presided.

Messrs. F. W. Averill and G. F. Hall, carrying on business as general brassfounders, stampers, and piercers at 131, Constitution Hill, Birmingham, under the style of Byham & Company, have dissolved partnership.

Messrs. H. T. Fowler and C. Kendall, carrying on business as brass casters, at 138, Conybere Street, Birmingham, under the style of the Enterprize Casting and Manufacturing Company, have dissolved partnership.

John Warner & Sons, Limited, engineers, etc., Spellman Street, Spitalfields, London, N.E., are devoting the whole of their attention in future to the church-bell founding department of their business. The other branches are being discontinued.

The partnership heretofore subsisting between Messrs. W. Walford and J. Walford, carrying on business as fender manufacturers and iron founders, at the Atlas Works, Charles Henry Street, Birmingham, under the style of T. J. Walford, has been dissolved.

Flockton, Tompkin & Company, Limited, Newhall Steel Works, Attercliffe, Sheffield, have terminated their agency agreement with Mr. J. W. Carr, 35, Queen Victoria Street, London, E.C. We understand that in future all business will be transacted from Sheffield.

J. & E. Wright, Limited, of the Universe Works, Birmingham, have appointed Messrs. Barnes & Bell, 79, St. George's Place, Glasgow, as their agents for the sale of wire ropes in Scotland and Cumberland. Messrs. Barnes & Bell have a warehouse and stores at Sunnyside Road, Coatbridge.

The firm of W. D. McLaren & Company, engineers, Ardgoil Engineering Works, Tarbet Street, Gourock, of which Mr. W. D. McLaren was the sole partner, was dissolved as at January 8. The business will be carried on by Mr. A. L. Wildig at the same address, under the style of A. L. Wildig & Company.

Messrs. T. C. Ormerod and M. W. Mills, carrying on business as millwrights and engineers, at Moss Foundry, Heywood, under the style of James Mills & Company, have dissolved partnership. Mr. M. W. Mills will in future carry on the business on his own account, under the style of James Mills and Company.

The British Lead Company, of 122, Newgate Street, London, E.C., have acquired from the Ribbon Metals Syndicate, Limited, 50, City Road, London, E.C., the British rights for the sale of "Ribbonite" lead for pipe-joint caulking, lead sheet, strip, etc., manufactured under the patents owned by the syndicate.

The partnership heretofore subsisting between Messrs. H. W. Umney and A. Peckett, carrying on business as consulting engineers and agents, at 46, King William Street, London, E.C., under the style of Umney & Peckett, has been dissolved. The business will be carried on in the future by Mr. H. W. Umney.

The partnership heretofore subsisting between Messrs. D. H. Hurley, J. R. Martin, G. Johnson, and A. E. Smith, carrying on business as engineers, at Stoney Stanton Road, Coventry, under the style of the Coventry Aero and Marine Engine Company, has been dissolved, so far as regards G. Johnson and A. E. Smith.

Williams, Foster & Company, and Pascoe Grenfell & Sons, Limited, Swansea, have just placed an order with Curran Brothers, 72, Bute Street, Cardiff, for ten furnaces to be erected on the Curran patent system of heating. This order is in addition to the furnaces which Messrs. Curran have already erected for the same firm.

The announcement is made in the American papers of the new engineering firm of S. T. Wellman & Son (H. G. Wellman), with offices in Cleveland, U.S.A. Mr. Wellman is still chairman of the board of directors of the Wellman-Seaver-Morgan Company, but the business of the new firm is entirely distinct from that of the latter company.

The firm of Smith & McIntosh, brassfounders, etc., 100, Victoria Road, Dundee, has been dissolved of mutual consent by the retiral of Mr. David McIntosh, one of the partners. The business will be continued by Mr. J. Ashton Smith, the remaining partner, on his own account under the same name, and he will discharge the liabilities.

Messrs. James W. Carr & Company, of 35, Queen Victoria Street, London, E.C., who have represented Flockton, Tompkin & Company, Limited, for 15 years, have concluded arrangements with an old established Sheffield firm of steel manufacturers. The Company's Sheffield address will in future be the Speedwell Steel Works, Soho Street, Sheffield.

Mr. Charles D. Phillips has decided to concentrate all his business at Newport. He has, therefore, removed his fitting shops and foundry from the Emlyn Works, Gloucester, down to Newport, where he recently purchased the Central Iron Works and Foundry, and will now operate the Central Works in conjunction with his Emlyn Works. The foundry has already been restarted.

At a recent meeting of the shareholders of James McEwan & Sons, Limited, Cyclops Foundry, Whiteinch, Glasgow, resolutions were passed to the effect that the company cannot, by reason of its liabilities, continue its business, and that it be wound up voluntarily, and that Mr. C. Ker, 115, St. Vincent Street, Glasgow, be appointed liquidator.

In order to facilitate the handling of iron and steel goods, experiments were made at Grimsby Docks, recently, with a magnet crane. Used in conjunction with the dockside electrical apparatus, the magnet speedily emptied a truck-load of bar iron and transferred it over the quayside to a waiting vessel. There is every likelihood of the apparatus being permanently introduced at the port.

At a board meeting, recently, of the Mannesmann Röhrenwerke, of Düsseldorf, the agreement concluded with the Wittener Stahlröhrenwerke, of Witten a.d. Ruhr, Westphalia, was ratified, according to which the Mannesmann Company, for a period of 30 years beginning March 1, 1912, is to take over the sale of all products of the Wittener Works. For further extensions of the Mannesmann Company the increase of the capital by 12,000,000m. will be proposed, and also the issue of a 4½ per cent. loan of 10,000,000m.

A. Harper, Sons & Bean, Limited, of the Waddam's Pool Ironworks, Dudley, have acquired a portion of the works formerly occupied by Thomas Astbury & Son, Limited, Smethwick Foundry, Rolfe Street, Smethwick, near Birmingham, and intend to open them in about six months. They are transferring a portion of their Dudley works, in which is carried on the manufacture of drop stampings and hot forgings, this having grown very considerably during the past few years. Extensive alterations are about to be made, and a quantity of heavy plant is to be put down.

The pattern-making business originally established by the late Mr. David Brown at East Parade, Huddersfield, and afterwards carried on by him and his sons under the style or firm of David Brown & Sons, has now been separated from the gear-cutting business carried on by the same firm, which has recently been taken over by the new company of David Brown & Sons, Limited, of Park Gear Works, Lockwood. The pattern-making business will be conducted in future under the style of Ernest M. Brown & Company, successors to David Brown & Sons, Mr. E. M. Brown having for some years had the management of that department.

J. W. Jackman & Company, Limited, have now removed from their old address, Chester Road, Manchester, to new premises which they have erected specially for the requirements of their business, known as Vulcan Works, Blackfriars Road, Manchester. In their new premises they are arranging to have every type of modern mould-

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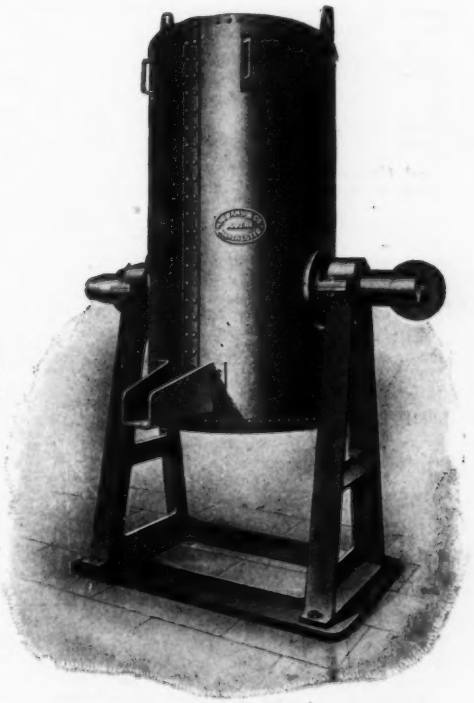
## EVANS'S NEW CUPOLETTE
**For Emergency Work.**



**James Evans & Co.,**
**Britannia Works,**
***Blackfriars,***
***MANCHESTER.***

Telegrams: "LADLES, MANCHESTER."

ing machine of value on show and at work, and are also exhibiting all other classes of the latest foundry machinery, including sand blast equipment, sand-treating plant, etc., etc. Messrs. Jackman inform us that in about one month's time they will be ready to receive visits from foundry managers, and submit to their inspection the complete installation actually at work, and there is no doubt that foundry managers will be able to obtain valuable information by inspecting what will be the largest exhibit of foundry machinery which has ever been installed in this or any other country.

After prolonged negotiations the suggested amalgamation of the Scottish iron companies has now reached a definite issue. In all there are about a score of such companies, and of these thirteen, having their works located mostly in the Coatbridge district, have signed the agreement to enter the combination. In accordance with the agreement steps will now be taken to fix the value of the various works and to ascertain their business connection with a view to arriving at a basis of capitalisation. Meantime it is estimated that the capital will amount to about £1,000,000 in debentures, preference, and ordinary shares. None of the ordinary shares will be issued to the public, but will be allotted to the vendors in part payment of the purchase price. The signatories to the agreement are as follows:—Archibald Baird & Son, Limited, Cairnhill Iron and Steel Works, Coatbridge; Downs & Jardine, Coats Iron and Steel Works, Coatbridge; Thomas Ellis, Limited, North British Iron Works, Coatbridge; Glencairn Iron and Steel Company, Limited, Flemington; C. F. Maclaren & Company, Stenton Iron Works, Wishaw; Hugh Martin & Sons, Coatbridge Iron Works, Coatbridge; A. & T. Miller, Globe Iron and Steel Works, Motherwell; John Spencer (Coatbridge), Limited, Phœnix Iron and Steel Works, Coatbridge; Wm. Tudhope & Son, Limited, Coatbridge; Victoria Iron and Steel Company, Limited, Coatbridge; Waverley Iron and Steel Company, Limited, Coatbridge; Wylie & Company, Clifton Iron and Steel Works, Coatbridge; and the Woodside Steel and Iron Company, Limited, Coatbridge. The new concern will be known as the Scottish Iron and Steel Company, Limited, and the combination will take effect as from January 1 last.

The twenty-first annual report of the Council of the Institution of Mining and Metallurgy states that the total membership at December 31 last was 2,191, as compared with 1,902 on December 31, 1909, a net increase of 289 in two years. The total membership on January 1, 1902, was 803, the net increase in the ten years ended December 31 last being 1,388. The Council have made three awards of the Gold Medal of the Institution during the year, two of which (those of Sir Julius Wernher and Mr. McDermott) may be regarded as special awards:—To Mr. E. P. Mathewson, in recognition of his eminent services in the advancement of metallurgy generally and especially in regard to copper; to Mr. Walter McDermott, in recognition of his special services in the equipment of the Bessemer Laboratory of the Royal School of Mines and as the Representative of the Institution on the Board of Governors of the Imperial College of Science and Technology during the period of its establishment and organisation; and to signalise his services in the advancement of metallurgical practice; to Sir Julius Wernher, Bart., in recognition of his personal services in the advancement of technological education and in the promotion of the highest interests of the mining and metallurgical professions. The Council have from time to time urged the desirability, in the interests of the Royal School of Mines, of the appointment of an Advisory Board, and they have the satisfaction of stating that such a Board has now been constituted by the Governing Body of the Imperial College of Science and Technology. The Institution is represented on the Board by Messrs. Arthur C. Claudet, Williams Frecheville, F. H. Hatch, Edward Hooper, Bedford McNeill, Hugh F. Marriott, H. Livingstone Sulman, and Edgar Taylor. Mr. H. Livingstone Sulman's period of office as President expired on March 21, and the Council state that Mr. Edward Hooper has been unanimously elected in succession to Mr. Sulman.

## Personal.

Professor Arnold, D.Met., of the Sheffield University, has been elected a Fellow of the Royal Society.

Mr. J. J. Carter, Mr. J. O'Hanlon, and Mr. W. L. Webb, have been elected directors of Crossley Bros., Limited.

The late Mr. D. J. Dunlop, sole partner of Messrs. J. Dunlop & Company, Port-Glasgow, left estate valued at £42,126 15s. 2d.

Mr. O. S. Hall, of Robert Hall & Sons, Limited, Hope Foundry, Bury (Lancs.), has been elected President of the Bury Chamber of Commerce.

Sir George H. Murray and Rear Admiral Sir Charles Ottley have been elected directors of Sir W. G. Armstrong, Whitworth & Company, Limited.

Mr. S. Sanders has resigned the chairmanship of John Wright and Eagle Range, Limited, and Mr. H. J. Yates, managing director, has been elected to the position.

The late Mr. J. White, managing director of Thomas Allan & Sons, Limited, left estate of the gross value of £49,549, of which the net personalty has been sworn at £47,110.

The late Mr. T. S. Furniss, a director of Sanderson Bros. and Newbould, Limited, left estate of the gross value of £244,589, of which the net personalty has been sworn at £232,302.

Mr. T. Jobson, until recently metallurgical expert to William Jessop & Sons, Limited, Sheffield, has left for New York to take up a post with the Crucible Steel Company of America.

The Royal Swedish Academy of Science in Stockholm has conferred upon Sir Robert Hadfield, F.R.S., the honour of electing him a foreign member as "a token of its appreciation of his excellent work in metallurgy."

Mr. R. Wilson, assistant manager and secretary to Hobson, Houghton & Company, Limited, Don Steelworks, Sheffield, has resigned that position to become director and commercial manager of John Holding & Company, Limited, Union Forge, Sheffield.

Sir Robert Hadfield made an interesting personal announcement at the meeting of Hadfield's Steel Foundry Company, Limited, on March 18, when he stated that he had accepted an invitation to join the Arbitration Court formed in connection with the Industrial Council.

Sir Chas. S. Henry, M.P., of C. S. Henry & Company, Limited, will preside at the 69th anniversary festival of the Royal Metal Trades' Pension Society, to be held at the hall of the Ironmongers' Company on June 24. Mr. H. C. Bond, J.P., of Richard Thomas & Company (Limited), will be in the vice-chair.

At the last meeting of the Lancashire Branch of the British Foundrymen's Association, the Chairman announced with regret that Mr. H. Sherburn had intimated his intention of resigning the office of hon. secretary of the Branch, being strongly of opinion that the position should be held by a member who resided in Manchester or the immediate neighbourhood.

Mr. R. Mason, a past-president of the Birmingham branch of the British Foundrymen's Association, has left this country for Australia, having been one of forty who have been selected by the Victorian Government as foundry experts to aid in the development of the industries out there. At a recent meeting of the branch, the Branch President (Mr. H. L. Reason) remarked that Mr. Mason would be remembered as one of the original members, and as having done much useful work for the Association generally. He was sure the members would like to send to Mr. Mason a message congratulating him upon his appointment, and expressing the hope that he would do well in his new sphere of labour. He moved that they request the hon. secretary to write to Mr. Mason in the terms suggested, and the motion was carried by acclamation.

# A NEW STEEL BARROW

(PATENTED)

## "BRABY'S BALANCED BARROW."

The Handiest and Cheapest Barrow in the market. Specially designed for coal, dross, ashes, etc. Its capacity is **25 per cent. greater** than the ordinary style, yet it can be wheeled with **half the labour**, and can be emptied **much more quickly**. It is a **perfectly balanced** barrow, and a full load can be **easily wheeled by a boy.**

**NOTE.—This Barrow can be taken right up to mouth of furnace and the ashes drawn into the barrow direct from the furnace.**

The "B.B.B."

**BRABY** for high grade **STEEL**
SHEETS & PLATES up to 15 FEET LONG.
RANGE of GAUGES 8 to 30 W.G.
RANGE of WIDTHS 12 to 60 in.

**BRABY** for improved wrought **STEEL**
BARROWS, BOGIES, TRUCKS, GUTTERS, PIPES, &c.

**BRABY** for Iron and **STEEL**
ROOFS and BUILDINGS.

**BRABY** for unbreakable **STEEL**
SASHES, CASEMENTS, and PUTTYLESS ROOFLIGHTS.

**BRABY** for galvanized corrugated **STEEL**
SHEETS: "EMPRESS" & "SUN" BRANDS

**FREDERICK BRABY & Co. Ltd.,** Eclipse Iron & Galvanising Works & Steel Sheet Rolling Mills, Petershill Road, GLASGOW.

Show Rooms and Aluminium Warehouse, 124, St. Vincent Street, Glasgow.
Rustless Iron, Galvanising and Copper Works, FALKIRK.

Also at London, Deptford, Liverpool, Bristol, Belfast and Dublin. CONTRACTORS to BRITISH and FOREIGN GOVERNMENTS. Teleg.—"Braby, Glasgow."

# Horace P. Marshall & Co.,

## FOUNDRY SPECIALISTS, LEEDS.

**Contractors to Admiralty, War Office, London County Council, Indian Railways, &c.**

## INVITE ENQUIRIES for all descriptions of FOUNDRY EQUIPMENT,

INCLUDING THE FOLLOWING:—

**Brass Furnaces**
**Cupolas**
**Core Machines**
**Core Stores (gas fired)**
**Core Ovens**
**Crucibles**
**Fettling Drums**
**Pig Iron Breakers**
**Pneumatic Chippers**
**Pneumatic Rammers, Drills, Hoists**
**Pneumatic Riddles &c., &c.**
**Air compressors for ditto.**

TELEGRAMS:—
**"SPECIALTY LEEDS."**

TELEPHONE:—
**1909 LEEDS.**

**Cupola Hoists**
**Moulding Machines (hand)**
**" " (power)**
**Moulding Boxes**
**Mould Driers**
**Ladles**
**Sand Mills**
**" Mixers**
**" Sifters**
**Foundry Sundries:—**
**Pattern Makers' Letters**
**Blowhole Cement**
**Brushes, Sieves, Chaplets &c.**

## New Companies.

CLEMMONS ALUMINIUM, LIMITED.—Capital £3,000 in £1 shares.

STOURBRIDGE ENGINEERS AND IRONFOUNDERS, LIMITED.—Capital £3,000 in £1 shares.

JOHN C. FULLER & SON, LIMITED.—Capital £10,000 in £1 shares, to carry on the business of engineers, etc.

M. DARNBOROUGH & SONS, LIMITED.—Capital £3,000 in £1 shares, to carry on the business of brassfounders, etc.

KENT METALS COMPANY, LIMITED.—Capital £2,000 in £1 shares. Registered office: 15, New Broad Street, E.C.

AMAZONAS ENGINEERING COMPANY, LIMITED.—Capital £50,000 in £1 shares, to carry on the business of engineers, etc.

JOHN H. STOREY & COMPANY, LIMITED.—Capital £10,000 in £1 shares, to carry on the business of engineers, etc.

MASHAL ENGINEERING COMPANY, LIMITED.—Capital £10,000 in £1 shares. Registered office: 84, Major Street, Manchester.

SAMUEL BIRKETT & SONS (CLECKHEATON), LIMITED.—Capital £2,500 in £1 shares, to carry on the business of brassfounders, etc.

NECHELLS METAL COMPANY, LIMITED.—Capital £500 in £1 shares. Registered office: 60, Mount Street, Nechells, Birmingham.

MAIDENHEAD IRONWORKS COMPANY, LIMITED.—Capital £1,000 in £1 shares. Registered office: The Ironworks, West Street, Maidenhead.

WILLIAM MCNEIL & COMPANY, LIMITED.—Capital £5,000 in £1 shares, to deal in engineering material. Registered office: 216, St. Vincent Street, Glasgow.

STANDARD SAND-BLAST MACHINE COMPANY, LIMITED.—Capital £6,000 in £1 shares, to carry on the business indicated by the title and to adopt an agreement with W. J. Smith.

GEORGE DUNN & COMPANY, LIMITED.—Capital £1,000 in £1 shares, to carry on the business of ironfounders, etc. Registered office: Albion Works, Bradford Road, Ballylean, Dewsbury.

ISAAC BEST & COMPANY, LIMITED.—Capital £5,000 in £1 shares, to carry on the business of founders, engineers, etc., to acquire an invention relating to high speed twist drills.

BRITISH ARC WELDING COMPANY (MERSEY), LIMITED.—Capital £20,000 in £1 shares, to take over and work a process for electrical welding under a licence given by the British Arc Welding Company, Limited, to H. & C. Grayson, Limited.

IMESON, FINCH & COMPANY (1912), LIMITED.—Capital £5,000 in £1 shares, to take over the business of electrical, mechanical, tramway, and general engineers, lately carried on by Imeson, Finch & Company, Limited, at Stockton-on-Tees.

INDUSTRIAL FOUNDRY AND ENGINEERING COMPANY, LIMITED.—Capital £4,000 in £1 shares, to carry on the business of founders, moulders, pipe casters, tube drawers, etc., to acquire the businesses carried on in Worcester as Walter H. Brickley & Company, and the industrial Foundry Company.

ANGLO-BRAZILIAN FORGING STEEL STRUCTURAL AND IMPORTING COMPANY, LIMITED.—Capital £75,000 in £1 shares, to carry on, in the United Kingdom, Brazil, and elsewhere, the business of importers, exporters, manufacturers, and warehousemen of and dealers in iron, steel, machinery, engines, boilers, etc., to establish offices in San Paulo and elsewhere in Brazil, or other parts of the world, and to adopt agreements (1) with W. A. Vaughan, and (2) with W. S. Vaughan, C. J. Dymond, and W. A. Vaughan. Registered office: Milburn House, Dean Street, Newcastle-on-Tyne.

## Deaths.

MR. S. DAWSON, of the Ryecroft Ironworks, Ashton-under-Lyne, died recently aged 68 years.

MR. JAMES DALE, coppersmith and engineer, 20, Emerson Street, Bankside, London, S.E., died recently aged 83 years.

THE death is reported of Mr. E. Dawson, of Dawson, Bentley & Company, Paragon Ironworks, Keighley, aged 64 years.

MR. W. CROSLAND, of Wm. Crosland, Limited, Bredbury, near Stockport, died recently at the age of 87 years.

MR. W. H. BUCKLEY, secretary to H. Lees & Sons, Limited, of the Park Bridge Iron Works, Ashton-under-Lyme, died recently, aged 61.

THE death is announced of Mr. W. Birch, Milton Street Ironworks, Broughton Lane, Lower Broughton, Manchester, at the age of 76.

THE death is announced of Mr. P. A. Williams, of Messrs. Philip Williams & Sons, Wednesbury Oak Ironworks, Tipton. The deceased gentleman was 83 years of age.

THE death took place on March 20 of Mr. John Ward, a partner in the firms of Messrs. Denny & Company, and Messrs. Wm. Denny & Bros., engineers and shipbuilders, of Dumbarton. Mr. Ward was in his 64th year.

MR. THOMAS COLVER died suddenly, at Gainsborough, on March 13, at the age of 61. For the last thirty years he was identified with the financial department of Messrs. Marshall, Sons & Company, Limited, of Gainsborough.

THE death is announced of Mr. Wm. Heap, who was, until his retirement from active business about eighteen months ago, the senior partner in the well-known firm of Messrs. Wm. Heap & Company, iron and steel merchants and engineers, of Royal Liver Building, Liverpool.

MR. JOHN TEASDALE, one of the founders of Teasdale Brothers, Limited, Bank Top Ironworks, Darlington, died on March 9. Mr. Teasdale, who was 66 years of age, was a native of Burneston, near Bedale, and in addition to his association with the works at Darlington, was interested in other branches of industry.

MR. J. H. TURNER, a director of P. & W. MacLellan, Limited, Clutha Works, Plantation, Glasgow, died recently. The deceased gentleman was born at Barrhead 57 years ago, and entered the company's service at the age of 16, rising to the position of director 15 years ago. He was a member of the Engineering Standards Committee.

BY the death of Mr. Frank Walters Bond, of Wargrave, Berks., a vacancy is created on the directorate of three companies — Richard Thomas & Company, Limited, the North-Eastern Steel Company, Limited, and Dorman, Long & Company, Limited; firms with which he was connected for many years. Though the deceased was in his 95th year, he had been in good health, his death occurring suddenly at Sidmouth on Friday, March 1.

THE sudden death was recently announced of Mr. T. P. Reay, chairman of Kitson & Company, Limited, Airedale Foundry, Hunslet, Leeds, at he age of 67. The deceased gentleman was one of the industrial pioneers of Leeds, and fitting recognition of that fact was made when, on the death of the late Lord Airedale, he succeeded to the position of chairman of the company. His association with the firm dated back well over half a century. He was but fourteen years of age when he entered the works of which in 1875 he became manager.

THE death occurred recently of Mr. B. Wright, who for about 50 years had held an official position at the Hartlepool Engine Works, serving under three generations of the Richardson family. Mr. Wright in 1847 opened out at Middleton the business which subsequently developed into the Hartlepool Engine Works. He was associated with all the extensions of the Hartlepool Engine Works down to 1896, when he retired.

# PURE METALS

**and ALLOYS. FREE from CARBON.**

**TITANIUM THERMIT**

**for**

**SOUND, STRONG, CLOSE-GRAINED CASTINGS.**

**Also FERRO VANADIUM and FERRO TITANIUM.**

Full Particulars and PRICES from—

## THERMIT LIMITED

Telegrams: "Fulmen, London."
Telephone: 3749 Central,

**27, Martins Lane, Cannon Street, E.C.**

**Works: 210a, Bow Road, E.**

# ELDERS FOUNDRY COKE

**AS SUPPLIED TO THE BRITISH ADMIRALTY DOCKYARDS.**

**The following, selected from numerous letters, are eminent testimony as to the quality of our celebrated "A.A.A." Coppee Foundry Coke, carefully selected, and despatched in sheeted wagons.**

From PECKETT & SONS, Bristol.

Bristol, October 25th, 1904.

We have been using your Selected Foundry Coke for some considerable time.
We have pleasure in stating that we are very pleased with it, as we find we get sounder and cleaner castings, more free from blowholes and other defects, than we formerly did.

From BOW, McLACHLAN & CO., LTD. (Paisley Foundry), Paisley, Glasgow.

Paisley, 12th March, 1909.

We have yours of 4th inst., and in reply have pleasure in stating that we have been using your Foundry Coke for several years for special purposes with highly satisfactory results.

## Elders Collieries, Ltd., Cardiff.

## PRICES OF METALS.

The following table shows the approximate latest prices and position of stocks of metals during the past two years:—

| METALS. | End Mch., 1912. | End Mch., 1911. |
|---|---|---|
| Iron—Scotch pig warrants ton | *57/10½ | *53/4½ |
| —Middlesbro' warrants ... ton | 51/11 | 47/7½ |
| —W.C. M/nos Bessemer ... ton | 67/6 | 66/0 |
| —Stock, Scotch ... ...tons | 1,000 | 1,000 |
| Copper—Chili bars, GMB ton | £70 12 6 | £54 7 6 |
| —Stock, Europe and afloat tons | 50,175 | 82,267 |
| Tin—English ingots ... ton | £200 10 0 | £188 10 0 |
| —Straits ... ... ... ton | £196 10 0 | £187 10 0 |
| —Stock, London, Holland, U.S.A., and afloat ...tons | 16,615 | 17,497 |
| Lead—English pig ... ton | £16 10 0 | £13 5 0 |
| Spelter—Ord. Silesian ... ton | £26 0 0 | £23 10 0 |
| Quicksilver (75lb)... bottle | £8 12 6 | £9 5 0 |
| Antimony—Regulus ... ton | £27 0 0 £27 10 0 | £33 0 0–£35 0 0 |

* Settlement price.

### CASTINGS.

In the Cleveland district the following are the nominal rates current for castings:—

| | £ s. d. | | £ s. d. |
|---|---|---|---|
| Columns (plain) ... ... ... ... | 6 10 0 | to | 6 15 0 |
| Pipes, 1½ to 2½ in. ... ... ... ... | 5 7 6 | to | 5 15 0 |
| ,, 3 to 4 in. ... ... ... ... | 5 2 6 | to | 5 5 0 |
| ,, 5 to 8 in. ... ... ... ... | 5 0 0 | to | 5 2 6 |
| ,, 10 to 16 in. ... ... ... ... | 5 0 0 | to | 5 2 6 |
| ,, 18 to 24 in. ... ... ... ... | 5 0 0 | to | 5 2 6 |
| Chairs ... ... ... ... ... ... | 3 12 6 | to | 3 15 0 |
| Floor plates (open sand) ... ... ... | 3 0 0 | to | 3 2 6 |

### SCRAP.

The quotations for scrap, subject to market fluctuations, are as follows: Heavy wrought (mixed), £2 9s. 0d.; light wrought, £1 5s. 0d.; heavy cast, £2 7s. 6d.; all per ton, f.o.b., London. Copper (clean), £64 10s. 0d.; brass (clean), £45 0s. 0d.; lead (usual draft), £15 5s. 0d.; zinc, £19 15s. 0d.; all per ton delivered merchant's yard


"ADAMANT CEMENT"

THE IRON CEMENT
FOR
FOUNDERS & ENGINEERS.

British Manufacture.

FREE SAMPLE AND PRICES FROM
SOLE MAKERS:—
CHARLES HALL & CO.,
NEWTOWN IRONWORKS,
Dixon Street, Dantzic Street,
MANCHESTER.

T. E. MANSERGH.

EVERY DESCRIPTION OF
MOULDERS'
PATENT WOOD, MINERAL and
COAL DUST BLACKINGS
MANUFACTURED.

Wheathill
Charcoal Works, SALFORD.

FOUNDRY CUPOLAS!

FOUNDRY LADLES!

Finest Workmanship and Materials.

SEND for QUOTATIONS
Our PRICES will interest YOU

The DERBY
BOILER Co., Ltd.,
DERBY.

GANISTER, CUPOLA BLOCKS, FIRE BRICKS,
FIRE CLAY.
*Silica Bricks, Tuyeres, Stoppers, Nozzles, &c.*
STEEL MOULDERS' COMPOSITION, SILICA CEMENT.

J. GRAYSON LOWOOD & Co., Ltd.,
DEEPCAR, nr. SHEFFIELD.

Telegrams: "LOWOOD, DEEPCAR."

*Established 1863.*

# JAS. DURRANS & SONS,

## Phœnix Works, Penistone, Near Sheffield.

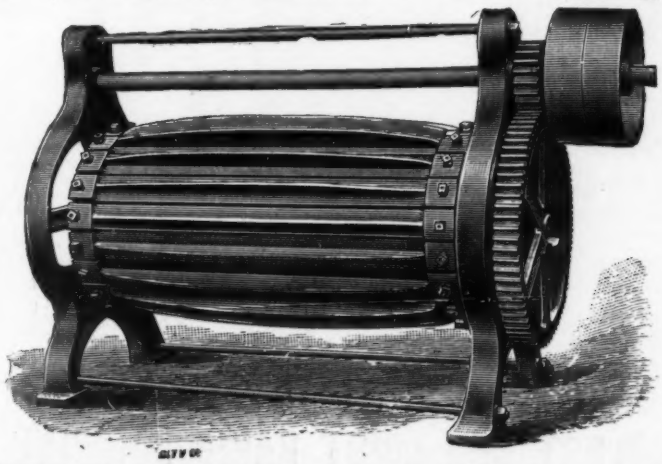
**Manufacturers of all**

## *FOUNDRY EQUIPMENTS*

**COMPOSITION BLACK LEAD, PLUMBAGO, CORE GUM, WHITE DUST & COAL DUST**

**Ladles, Cupolas, Fire Bricks, Gannister, Stone Flux, Loam and Sand Mills, Casting Cleaners, Studs, Chaplets, Pipe Nails, Sprigs, Brushes, Wire Brushes, Core Ropes, Bellows, Buckets, Spades, Forks, Riddles, Sieves, Barrows, Etc.**

## Improved Foundry Rattler or Fettling Drum.



**These Machines are invaluable for a Foundry, doing a larger amount of work of a superior quality, in a much shorter time than can be done by hand, without skilled labour.**

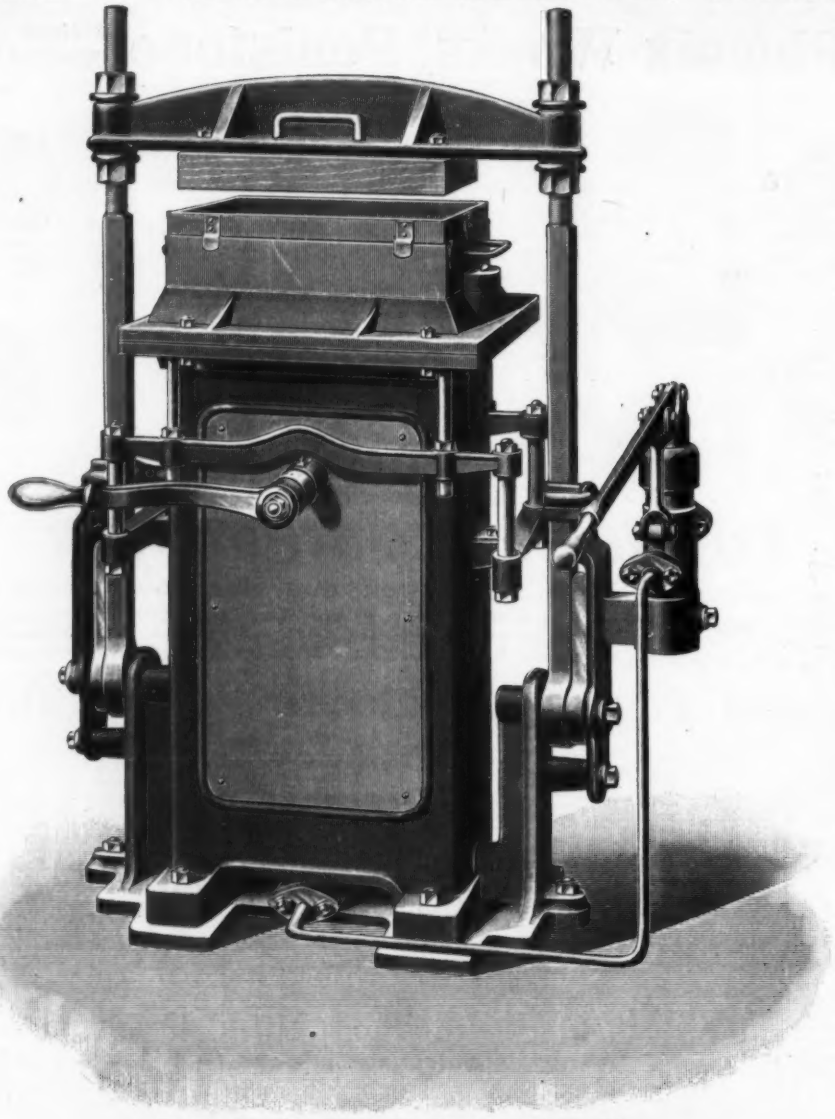
The following testimonial explains itself :—

"Dear Sirs,—We have been using your best Blacking for a large number of years, and always use it on our large Ingot Moulds, which, as you know, we have made up to 85 tons in weight.

Yours faithfully, THE BRIGHTSIDE FOUNDRY & ENGINEERING CO., LD.

# The London Emery Works, Co., PARK WORKS,

TELEGRAMS: "NAXIUM, LONDON." TOTTENHAM, LONDON, N. TELEPHONE: TOTTENHAM 158 (TWO LINES)



**Hydraulic Moulding Machine. Pattern P.**

## THE SIMPLEST AND MOST RAPID MACHINE MADE.

The working parts are so conveniently arranged and operate with such facility that a mould can be rammed and put down on the floor in ¾ minute. This means that the moulder can produce three times as many boxes as by hand and, further, every mould is perfect and all castings alike.

INVALUABLE in ALUMINIUM, BRASS and MALLEABLE IRON FOUNDRIES. Send us sample castings or drawings of your work and we will tell you what can be done.

**Sort them out Now, and Write To-day.**

# THE BUYER'S GUIDE

*Addresses and further information will be found by reference to the Firm's Advertisement.*

**Abrasive Wheels.**
Evans, J. & Co.
London Emery Works Co.
Jackman, J. W., & Co., Ltd.

**Air Compressors.**
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Phillips, J. W. & C. J.
Thwaites Bros., Ltd.
Tilghman's Patent Sand Blast Co., Ltd.

**Air Compressors (Electrically Driven).**
Jackman, J. W., & Co., Ltd.
Marshall & Co. Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

**Air Compressors (Steam).**
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

**Air Compressors (Belt).**
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Tilghman's Patent Sand Blast Co., Ltd.

**Aluminium.**
British Aluminium Co, Ltd.

**Annealing.**
Evans, J. & Co.
Phillips, J. W. & C. J.

**Ash Crushing and Washing Machines.**
Evans, J., & Co.
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Phillips, J. W. & C. J.

**Barrels (Tumbling).**
Alldays & Onions Pneumatic Eng. Co., Ltd.
Evans, J., & Co.
Hall, Charles, & Co.
Jackman, J. W., & Co., Ltd.
London Emery Works Co.
Marshall, H. P., & Co.
Phillips, J. W. & C. J.
Tilghman's Patent Sand Blast Co., Ltd.

**Barrows.**
F. Braby & Co., Ltd.
Durrans, J., & Sons.
Evans, J., & Co.
Hall, Charles, & Co.
Jackman, J. W., & Co., Ltd.

**Bellows.**
Alldays & Onions Pneumatic Eng. Co., Ltd.
Evans, J., & Co.
Durrans, Jas., & Sons.
Hall, Charles & Co.
Jackman, J. W., & Co., Ltd.
Olsen, Wm.

**Blacklead.**
Durrans, J., & Sons.
Evans, J., & Co.
Hall, Charles, & Co.
Jackman, J. W., & Co.,Ltd.
Olsen, Wm.
Walker, I. & I.
Wilkinson & Co., Thos., Ltd.

**Blowers.**
Alldays & Onions Pneumatic Eng. Co., Ltd.
Buffalo Forge Co., Ltd.
Davies, T., & Son.
Dempster, R. & J., Ltd.
Evans, J., & Co.
Jackman, J. W., & Co., Ltd.
Keith, J., & Blackman, Co., Ld.
London Emery Works Co.
Marshall, H. P., & Co., Ltd.
Phillips, J. W. & C. J.
Samuelson & Co., Ltd.

**Blowers**—*cont*
Thwaites Bros., Ltd.
Ward, T. W., Ltd.

**Buffing and Polishing Machines.**
Jackman, J. W., & Co., Ltd.
London Emery Works Co.

**Casting Cleaners.**
Durrans, J., & Sons.
Evans, J., & Co.
Jackman, J. W., & Co., Ltd.
Marshall & Co., Horace P.
Pneumatic Engineering Appliances Co., Ltd.
Tilghman's Patent Sand Blast Co., Ltd.

**Cement.**
Dyson, J. & J.
Evans, J., & Co.
Hall, Charles & Co.
Jackman, J. W., & Co., Ltd.
London Emery Works Co.
Lowood, J. Grayson, & Co., Ld.
Marshall & Co., Horace P.
Metalline Cement Co.
Olsen, Wm.
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| PAGE | NAME. | ADDRESS. | TELEGRAPHIC ADDRESS. | TELEPHONE NO. |
|---|---|---|---|---|
| 312 | Adjustable Moulding Machine Co., ... | Coventry ... ... ... ... ... | — | — |
| 265 | Alldays & Onions, Ltd.... ... ... ... | Birmingham ... ... ... ... ... | Alldays, Birmingham ... ... | 23 Victoria |
| 266 | Braby, F., & Co., Ltd. ... ... ... ... | Petershill Road, Glasgow... ... ... | Braby, Glasgow ... ... ... | — |
| 264 | Bradley, T. & I., & Sons, Ltd. ... ... | Darlaston ... ... ... ... ... | Bradley, Darlaston ... ... ... | — |
| 262 | Britannia Foundry Co. ... ... ... | Coventry ... ... ... ... ... | Stoves, Coventry ... ... ... | 251 |
| 264 | British Aluminium Co., Ltd. ... ... | 109, Queen Victoria Street, S.E. ... | Cryolite, London ... ... ... | 4315 London Wall |
| 318 | Cumming, William, & Co., Ltd. ... ... | Maryhill, Glasgow ... ... ... ... | Prudence, Glasgow ... ... ... | P.O. M. 25 |
| C ii. | Dempster, R. & J., Ltd. ... ... ... | Oldham Road, Manchester ... ... | Scrubber, Manchester ... ... | — |
| 259 | Davies, T., & Sons ... ... ... ... | West Gorton, Manchester... ... ... | Tuyere, Manchester ... ... ... | 70 Openshaw |
| 314 | Derby Boiler Co., Ltd. ... ... ... | Derby ... ... ... ... ... | Welded, Derby ... ... ... | 100 Derby |
| 315 | Durrans, Jas., & Sons ... ... ... ... | Penistone, nr. Sheffield ... ... ... | Durrans, Penistone ... ... ... | — |
| C. ii. | Dyson, J. & J. ... ... ... ... ... | Sheffield ... ... ... ... ... | Dyson's, Stannington... ... ... | 702 Sheffield |
| 313 | Elders' Collieries Ltd. ... ... ... | Cardiff ... ... ... ... ... ... | Elder, Maesteg ... ... ... ... | 10 |
| 268&311 | Evans, J., & Co. ... ... ... ... ... | Manchester ... ... ... ... ... | Ladles, Manchester ... ... ... | 2297 |
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| | Fyfe, J. R. & Co. ... ... ... ... | Shipley, Yorks ... ... ... ... | Brick, Shipley ... ... ... ... | 59 Shipley |
| 258 | Goldendale Iron Co., Ltd. ... ... ... | Tunstall, Stoke-on-Trent ... ... ... | Goldendale, Tunstall, Staffs ... | — |
| 265 | Hall, Charles & Co. ... ... ... ... | Dantzic Street, Manchester ... ... | — | 5814 City |
| 264 | Harris & Pearson... ... ... ... ... | Stourbridge ... ... ... ... ... | Fireclay, Stourbridge ... ... | 7 Brierley Hill |
| 262 | Hislop, R. & G. ... ... ... ... ... | Paisley ... ... ... ... ... ... | Gas, Paisley ... ... ... ... | 331 Paisley |
| 260 | Hodges, R. I., & Co. ... ... ... ... | 14, Devonshire Sq., Bishopsgate, E.C. | — | — |
| C. iv. | Jackman, J. W., & Co. ... ... ... ... | Caxton House, S.W. ... ... ... | Molders, London ... ... ... | 30 Victoria |
| 265 | Keith, James, & Blackman, Co., Ltd... | 27, Farringdon Avenue, London ... | James Keith, London ... ... | 6194 H'lb'rn(4 lines |
| 260 | King, Bros. (Stourbridge), Ltd. ... ... | Stourbridge ... ... ... ... ... | King Bros., Stourbridge ... ... | — |
| 314 | Kitchen & Co. ... ... ... ... ... | Derby ... ... ... ... ... | Welded, Derby ... ... ... | 100 Derby |
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| 263 | Macdonald, J. & Son, Ltd. ... ... ... | Maryhill, Glasgow ... ... ... | Compressor, Glasgow ... ... | 161 Mary Hill |
| | Mansergh, T. E. ... ... ... ... | Wheathill Charcoal Works, Salford | — | — |
| | Marshall, H. P., & Co. ... ... ... ... | Leeds ... ... ... ... ... .. | Specialty, Leeds ... ... ... | 999 Leeds |
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| 319 | Naish & Croft ... ... ... ... | 141, Whitehead Road, Aston Manor | Natrecord, London ... ... ... | 918 Hop |
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| 265 | Portway, C. & Son ... ... ... ... | Halstead, Essex ... ... ... ... | Portway, Halstead, Essex ... ... | 10 P.O. Halstead |
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| 264 | Walker, I. & I. ... .. ... ... ... | Rotherham ... ... ... ... ... | — | — |
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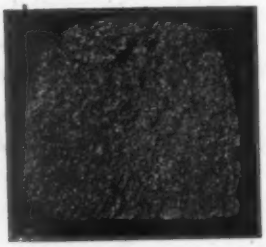
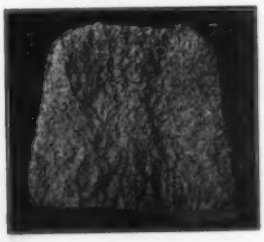
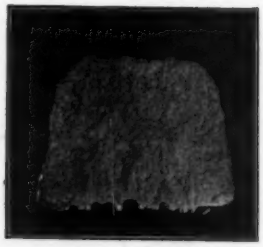

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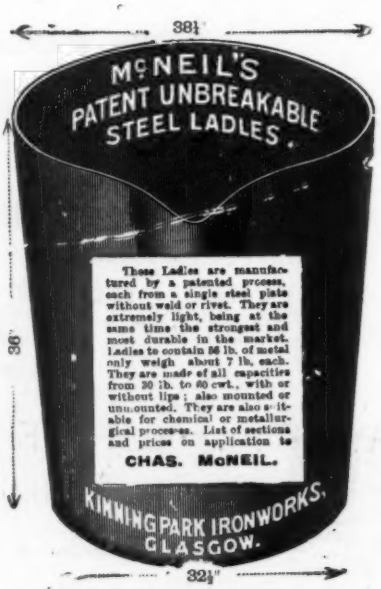
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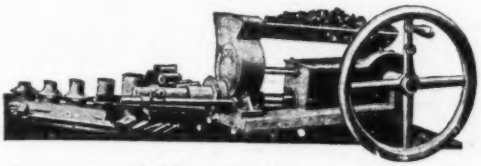

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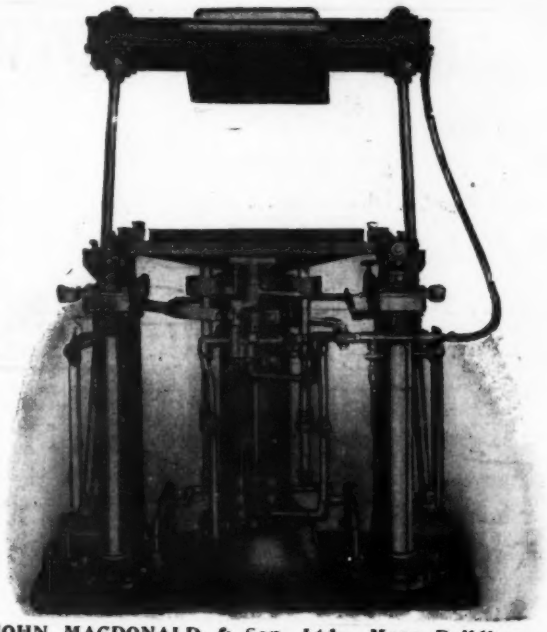

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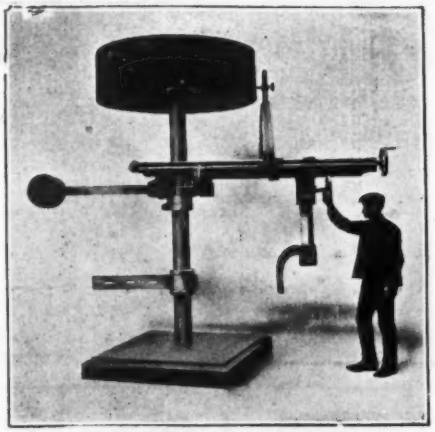

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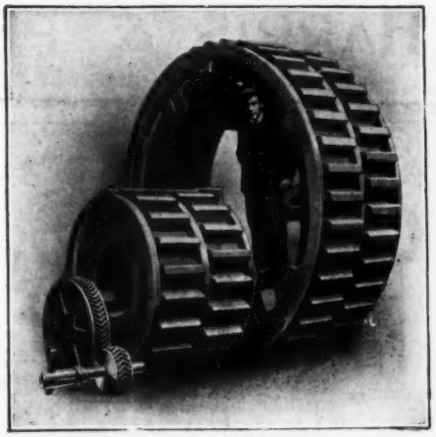

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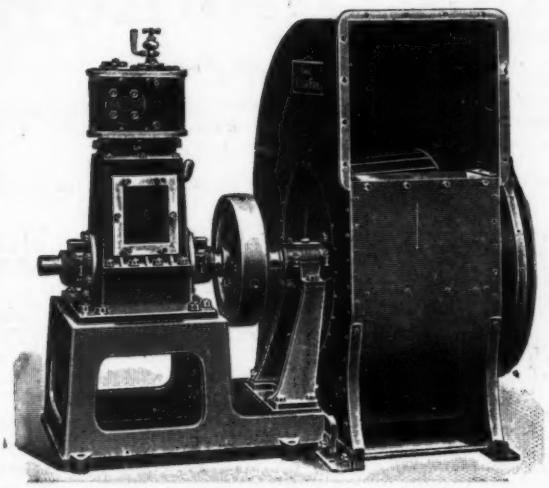

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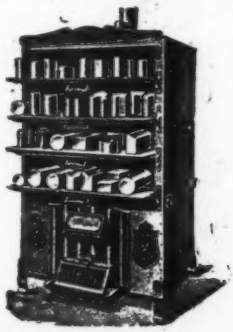

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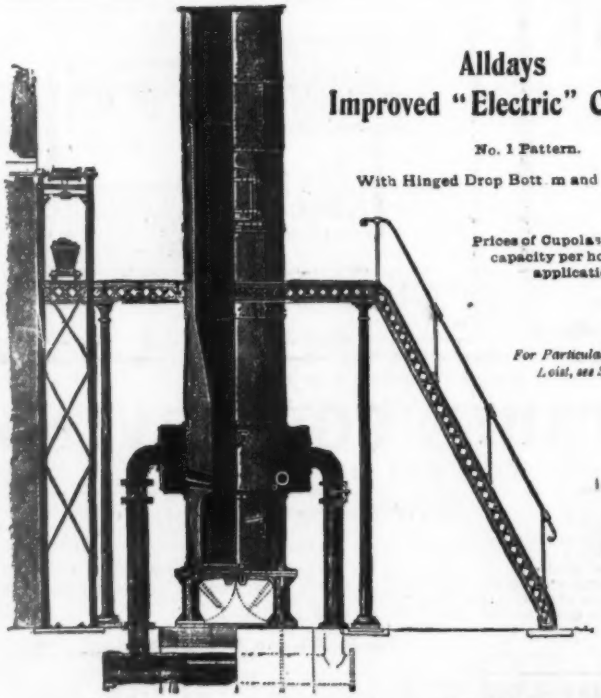

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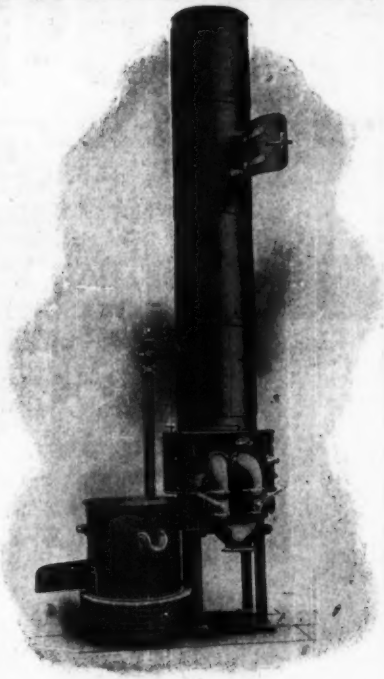

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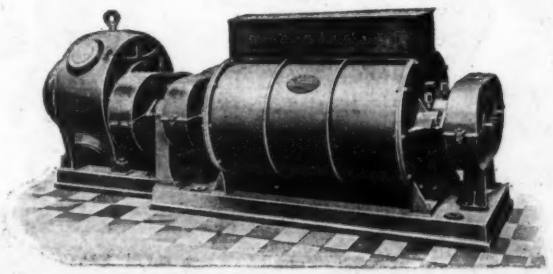

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